AN ANALYSIS OF RENEWABLE ENERGY, ENERGY EFFICIENCY, AND CARBON OFFSETS AT DUKE UNIVERSITY

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Executive Summary

Many universities around the world are embarking on voluntary efforts to become climate neutral in order to combat global warming. In 2007, Duke University adopted its own goal to be climate neutral by 2024, and the University's Office of the Executive Vice President established the Duke Carbon Offsets Initiative (DCOI) in June 2009 to develop a strategy for meeting this goals. As the client for this report, the DCOI charged the Masters team with preparing a purchasing guide to aid its decision making and requested an analysis of several options: reducing on-campus emissions through improving energy efficiency, buying carbon offsets on the market, creating carbon offsets through local projects, purchasing Renewable Energy Credits (RECs), and developing renewable energy resources on-campus. This report sets forth a recommended strategy to meet the carbon offsets goals, including a timeline of purchases and an overview of costs. Given the University's role as an institution motivated by both financial and non-financial goals, such as education and economic benefits to the local community, combinations of purchasing options are presented in three portfolios. They are: the cheapest portfolio, the portfolio yielding the greatest co-benefits to the community and university, and the portfolio balancing costs and benefits. A sensitivity analysis examined potential changes in the policy landscape that would affect the purchasing decisions favorable to Duke, including a price on carbon; changes in the cost of renewable energy; and a federal Renewable Portfolio Standard.

The second section of the report looks at potential projects and purchasing options for each of the categories: forestry offsets, methane capture offsets, energy efficiency, and renewable energy/renewable energy credits. The projects include both local Duke-developed projects and projects developed by outside vendors and then purchased by Duke University.

The third section of the report discusses the three different portfolios options that Duke could pursue. The first option is a lowest cost portfolio that minimizes the amount Duke would pay to achieve carbon neutrality through the purchase and development of only the lowest cost projects. The second portfolio option is a high co-benefit portfolio that maximizes the economic, social, and environmental benefits to the University in achieving carbon neutrality. The final portfolio is a balanced portfolio that blends the two previous portfolios to maximize co-benefits, minimize costs, and mitigate risk through project diversity.

The cheapest portfolio includes energy efficiency through behavioral changes on campus, purchased methane capture offsets, and methane capture offsets generated through local projects. The highest co-benefits portfolio, in contrast, includes Duke-developed forest offsets and Duke-developed methane capture offsets, while the balanced portfolio contains nine different projects across energy efficiency, renewable energy, and carbon offsets.

The final section of the report focuses on a variety of sensitivity considerations, such as a change in the price of carbon emissions, renewable energy, and electricity, as well as implementation of a federal Renewable Portfolio Standard. Any of these occurrences may greatly influence the recommended projects presented to DCOI and the relative attractiveness of different options.

Therefore it is important to mention these in the interest of guiding the DCOI's consideration of future offset and REC purchases, as well as on campus efficiency and renewable energy measures.

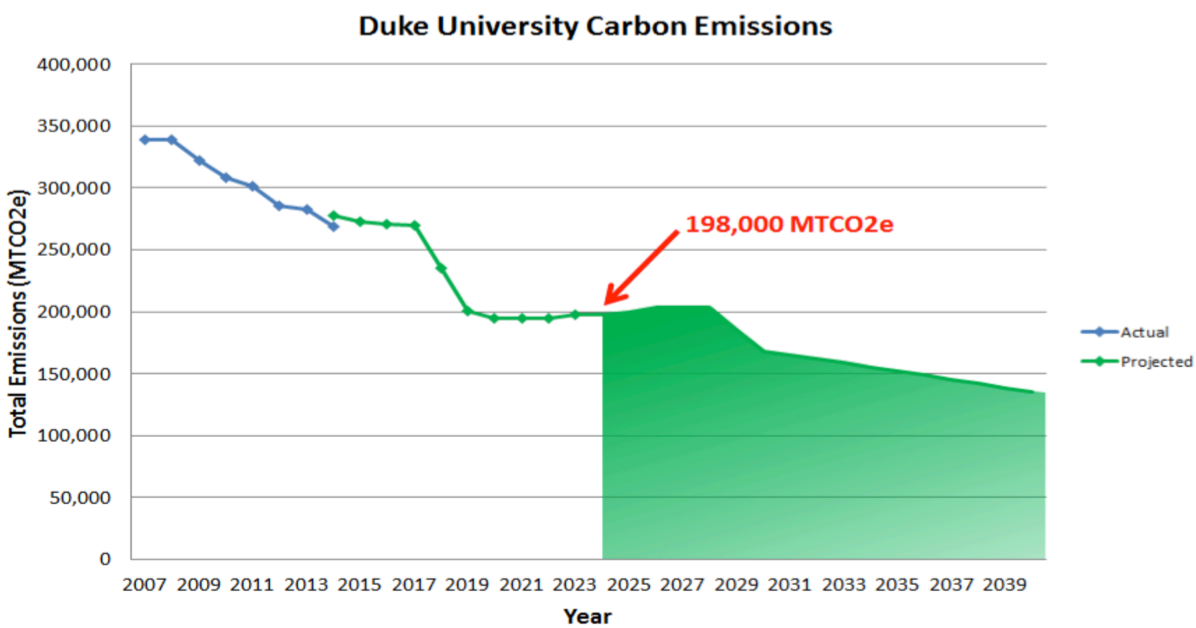
Ultimately it is recommended that the DCOI pursue the balanced portfolio approach to achieve carbon neutrality. This approach will yield the greatest project diversity while maximizing co-benefits and minimizing costs to better manage future risk and uncertainty.

Introduction

In 2007, Duke President Richard Broadhead signed the American College & University Presidents Climate Commitment (ACUPCC). By signing the commitment, Duke pledged to eliminate or offset all campus greenhouse gas emissions and developed a Climate Action Plan (CAP) that set a goal to be climate neutral by 2024. This will require the University to mitigate or offset approximately 375,000 metric tons of CO_2 equivalent ($MTCO_2e$) that would otherwise be emitted under a business as usual approach[1]. In this regard, the majority of the University's efforts will focus on the implementation of transportation and building energy improvements recommended by the CAP. Examples of these measures include completed strategies such as the transition from a coal-fired steam plant on campus to a natural gas powered plant and current strategies such as lighting retrofits, the use of renewable energy sources, financial incentives for alternative transportation, the improvement of regional transportation, and green building infrastructure.

While the University plans to aggressively pursue GHG emissions reduction on-campus, improvements in energy efficiency and transportation will not be enough to reach climate neutrality. Emissions that cannot be mitigated through these measures must be offset. Specifically, the University will need to offset roughly 198,000[2] $MTCO_2e$ per year starting in 2024[3].

Figure 1. Year-to-date and projected carbon emissions for Duke University



[1] Duke Climate Action Plan. 2009. http://sustainability.duke.edu/climate_action/Duke%20Climate%20Action%20Plan.pdf
[2] From file given to group by DCOI: 2014.08.06 Duke CAP_University-SOM_tracking_je10022014
[3] Polk, E and Potes, A. 2008. The role of offsets in meeting Duke University's commitment to'climate neutrality': a feasibility study. http://sustainability.duke.edu/documents/dukeoffsets.pdf

To better understand how the University will offset these emissions, the Duke Carbon Offsets Initiative (DCOI) was established in 2009. The goal of the initiative is to develop the University's strategy for meeting its offset goals in a way that provides local, state, and regional environmental, economic, and societal co-benefits. Importantly, the DCOI requires that any and all offsets meet the PAVER criteria[4]:

- **Permanent:** The reduced or avoided carbon emissions cannot be released back into the atmosphere, and will last in eternity
- **Additional:** The offsets are generated from a project that would have not occurred in a business-as-usual scenario
- **Verified:** It must be demonstrated that the project is generating carbon offsets as described and is monitored through an independent third party
- **Enforceable:** The carbon offsets must be backed by regulations and contracts which define the creation and clarify the ownership
- **Real:** The carbon offsets must represent actual reductions, which are under approved protocols and calculated correctly

Working towards the goal of climate neutrality by 2024, this analysis presents a portfolio approach that draws upon a variety of methods to generate carbon offsets. Currently, the DCOI mitigates carbon through two different projects. The first is a swine waste management project started in 2011 with Google and Duke Energy. The second is a home energy efficiency retrofit project targeted towards Duke employees. Additionally, the DCOI provides opportunities for individuals, departments at Duke, and special events to purchase offsets for emissions that cannot be avoided (such as employee travel). In the future, the DCOI plans to explore hands-on, interactive partnerships with businesses and other organizations to generate further offsets.

Project Objectives

Since Duke University's climate neutrality goal will require Duke to offset approximately 198,000 metric tons of carbon dioxide by 2024, our goal for this project is to assist Duke University and Duke's Carbon Offset Initiative in achieving its climate neutrality goal through the development of a portfolio that includes several different carbon offset strategies. This portfolio analyzes different methods to attain climate neutrality through the presentation of approaches that include both costs and benefits of each offset project. Each strategy evaluates the financial feasibility of the carbon offset or renewable energy purchase, the most appropriate location (if any) for the offset, and the additional benefits including environmental, societal, educational, and economic benefits to Duke and the surrounding North Carolina communities. The definition and scope of each benefit is shown in the **Appendix H**. The portfolio assumes that current offset projects such as the Loyd Ray Farms

[4] Center for Resource Solutions. 2010. Renewable Energy Certificates, Carbon Offsets, and Carbon Claims. http://www.resource-solutions.org/pub_pdfs/RECs&OffsetsQ&A.pdf

Project, distribution of solar generation to employees, increased energy efficiency on Duke's campus, and partnerships with local businesses achieve their goals. It then examines options for the purchase and development of new carbon offsets for the University to pursue.

In terms of Duke's priorities, the University wants to remain a leader in environmental stewardship and education and to become a leader climate neutrality amongst colleges and universities nation-wide. Therefore, it is important to invest in smaller, local offset projects that would serve as a hands-on academic tool for the Duke student body. Additionally, education of younger generations on greenhouse gas emissions and the carbon-offset market are critical pieces in the creation of a sustainable society in the future. This portfolio will provide environmental, social and economic benefits to Durham since Duke values fostering a healthy relationship with the surrounding communities. Since Duke's Climate Action Plan also focuses on decreasing campus emissions, student and faculty engagement, awareness, and education will be a critical part of decreasing overall energy consumption and a critical part of the criteria used in evaluating other local offsets.

Methodology-Portfolio Approach

Carbon Management Hierarchy

Energy efficiency program, renewables, and carbon markets are included in the portfolio analysis, because they cover all parts of the carbon management hierarchy. Similar to the "Waste Hierarchy"[5] approach, the concept of carbon management hierarchy includes four different categories:

- **Avoid:** this is the first priority under the carbon management hierarchy and aims to eliminate energy consumption for different carbon-intensive actives, such as alternative and lower emission transportation options, more efficient lighting and decreased plug loads.
- **Reduce:** the next step in carbon management is to reduce any unnecessary energy consumption with the most energy efficient equipment available. This category could be achieved by retrofitting lights and adopting energy efficient appliances.
- **Replace:** the second to the last priority focuses on how energy is generated. One could accomplish this category by replacing high-carbon energy sources with low-carbon energy sources, such as purchasing green energy generated from solar or wind, rather than fossil fuels. Other options may also include REC purchases.
- **Offset:** according to the hierarchy, organizations can purchase carbon offsets for the emissions that could not be eliminated by the previous three options. Various types of carbon offsets options are available in the market including agricultural methane, forestry, landfill methane, etc.

[5] Wolfe, Philip, 2005. *A Proposed Energy Hierarchy*. WolfeWare. http://www.wolfeware.com/library/publications/EnergyHierarchy.pdf

The actions on the left side of the hierarchy are more transformative and have a longer lasting effect for reducing an organization's emissions baseline. The order of the hierarchy is not purely based on the price of the emission mitigation. The three actions on the left side can be implemented within an organization before purchasing offset from an external party.

Energy Efficiency

Energy efficiency has the potential to lower the amount of GHG emissions that will need to be offset by 2024 to reach climate neutrality[6]. Since the 2009 Climate Action Plan, Duke has taken several steps towards reducing overall emissions on campus through energy efficiency. First, Duke transitioned to a more efficient boiler in the steam plant run entirely on natural gas. This alone has contributed to lowering the 2007 Scope 1 (all direct GHG emissions) energy emissions by 36% for Duke University's campus[7]. Additionally, the academic and university buildings have undergone energy efficiency retrofits such as the construction of more efficient air handlers, fume hood retrofits including variable air volume hoods, the installation of occupancy sensors, improved HVAC scheduling, and LED upgrades in both interior and exterior lights. Duke currently has 29 LEED certified buildings with a goal that all new construction and renovations meet the LEED Silver criteria[8].

According to Duke's CAP, energy efficiency on campus will significantly contribute towards meeting Duke's greenhouse gas commitments[9]. A major area for improvement that is being neglected is improved energy efficiency in dorms and apartments on Central Campus. Currently, the Energy Manager at Duke University, Steve Palumbo, and Energy Engineer, Casey Collins, manage university and academic buildings[10]. Athletics and Housing, Dining, and Resident Life (HDRL) are separate entities and self-manage their energy usage. By focusing on efforts to improve energy efficiency within dorms on campus (under HDRL), this research would assist in mitigating carbon using an approach that is not already in place at Duke.

Another way to utilize energy efficiency as an offset method is through energy efficiency credits (EECs). An EEC is defined as a carbon-equivalent emission reduction, removal, or avoidance

[6] Duke Climate Action Plan. 2009. http://sustainability.duke.edu/climate_action/Duke%20Climate%20Action%20Plan.pdf
[7] Ibid
[8] Ibid
[9] Ibid
[10] Personal conversation with Casey Collins of Duke Facilities Management.

through an energy efficiency retrofit or project that lowers the overall energy usage from the business-as-usual scenario[11]. EEC is the equivalent of 1 MWh of energy saved through energy efficiency. For example, when a utility helps a home or business owner reduce their overall energy use, they are granted an EEC for each MWh of electricity saved. Improving energy efficiency at alternate locations (such as employees' homes) establishes these types of offsets or EECs[12]. In 2013, DCOI launched the Home Energy Affordability Loan Program (DCOI-HEAL). A pre-pilot program was first conducted and resulted in an average energy savings of 13% in employee homes[13]. This was accomplished through improved education of employees around the topic of energy conservation and energy retrofits discovered through student-led energy audits. In 2014, the DCOI-HEAL pilot launched in 50 different employee homes. This pilot is helping to reduce carbon emissions and energy costs throughout the Durham community while producing EECs for the university to use as offsets. Co-benefits of this program include increased community engagement and awareness, improved public relations for the university, and additional educational opportunities for students who participated in the energy audits[14].

Renewable Energy and RECs

Compared to carbon offsets and energy efficiency, renewable energy does not constitute a significant component of Duke's 2009 Climate Action Plan until 2030. In the short-term, the only renewable energy option evaluated to reduce emissions was producing electricity using solar photovoltaic (PV) arrays. Specifically, the DCOI Energy Subcommittee recommended that Duke install 4MW of solar PV atop the Smith Warehouse Building and various parking garages by 2012. At an estimated cost of roughly $12 million, this solar PV capacity would produce up to 7 million kWh per year.[15] These systems would reduce the amount of electricity purchased from Duke Energy, and as a result, offset 3,500 $MTCO_2e$ in 2012. This impact would decrease to only 350 $MTCO_2e$ in 2050 as Duke Energy lowers its own carbon footprint. [16]

As of 2015, the only solar PV installed on campus is a 45 kW system on top of Environment Hall and 3 kW system on Duke's Smart Home – well short of the 4MW recommended by the Energy Subcommittee. Because Duke is a non-profit entity, it is unable to claim the tax credits that have made the development of solar PV economically viable in recent years. Moreover, utilities in North Carolina are regulated, which prevents third party power purchase agreements. Consequently, the

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[11] Wiess, J. and Vujic T. 2014. Financing Energy Efficiency-Based Carbon Offset Projects at Duke University.
[12] Duke Carbon Offsets Initiative. 2015. Duke Employee Residential Energy Efficiency Pilot Program. http://sustainability.duke.edu/carbon_offsets/efficiency.php
[13] Ibid
[14] Ibid
[15] 2009 cost estimates assume Duke could take advantage of solar tax credits. PV production projections assume a 20 percent utilization factor.
[16] Duke Climate Action Plan. 2009. http://sustainability.duke.edu/climate_action/Duke%20Climate%20Action%20Plan.pdf

only solar PV financing structure currently available to Duke that makes use of the tax credits is a lease-back arrangement.[17] This structure is costly, difficult to execute, and draws out the development process, making solar PV economically unfeasible for the University.

Alternatively, by 2030, Duke may convert the West and East steam plants to utilize biogas from an herbaceous renewable resource such as woody waste. This transition would reduce the amount of carbon to be offset, as emissions from burning this fuel would not count towards the University's GHG footprint. At a capital cost of $25 million, this conversion would account for 15.9% of Duke's projects BAU emissions in 2050.[18] Unfortunately, biomass options evaluated for the existing West Campus Steam plan were found to be impractical due to its location on campus and the increase in truck traffic required for delivering fuel to the plant.[19] Thus, as it currently stands, it is uncertain that Duke will achieve the steam plant biomass conversions outlined in the 2009 CAP.

Despite falling short of the expectation outlined in the 2009 Climate Action Plan, renewable energy still offers significant potential for moving Duke closer to climate neutrality. As renewable energy markets mature and technology improves, the levelized cost of electricity generation from such sources continues to drop – particularly for solar PV.[20] With decreasing costs come greater opportunities for Duke to develop economically viable renewable energy projects. These projects could be developed directly on campus or off-campus in conjunction with Duke-led initiatives, other universities, or Duke Energy. However, it is important to understand that renewable energy, whether generated or purchased, should be treated as an emissions reductions rather than an offset.[21]

Alternatively, Duke University could look to purchase renewable energy credits (RECs). A REC represents the rights to the non-power qualities of renewable electricity generation. In this case, it is the carbon emissions avoided by generating 1 MWh of electricity using a renewable based source as opposed to conventional fossil fuel based generation. This instrument can be applied to offset the University's Scope 2 emissions (GHGs generated from purchased electricity), which constitute 95% of electricity usage and 43% of Duke's carbon emissions as of 2014.[22] Furthermore, the EPA contends that purchasing RECs supports new renewable energy generation by sending a market demand signal and providing financial support for new renewable energy projects.[23] Through REC purchases, Duke would help to bring new renewable electricity facilities online, reducing the amount of carbon dioxide emitted by the electricity sector.

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[17] See Appendix B for a financial flow diagram of the lease-back structure

[18] Duke Climate Action Plan. 2009. http://sustainability.duke.edu/climate_action/Duke%20Climate%20Action%20Plan.pdf

[19] Ibid

[20] REN21. 2014. Renewables 2014: Global Status Report. http://www.ren21.net/portals/0/documents/resources/gsr/2014/gsr2014_full%20report_low%20res.pdf

[21] Polk, E and Potes, A. 2008. The role of offsets in meeting Duke University's commitment to 'climate neutrality: a feasibility study. http://sustainability.duke.edu/documents/dukeoffsets.pdf

[22] Scope 2 refers to indirect emissions generated in the production of electricity consumed by the University

[23] United States Environmental Protection Agency. 2014. Environmental value of purchasing RECS. http://www.epa.gov/greenpower/rec.htm

Historically, there have been concerns regarding a REC's contribution to emissions reductions as these instruments may not face the same regulatory standards as carbon offsets. Dated RECs have been sold at low costs, causing some to question if such purchases support the development of new renewable electricity and additional emissions reductions.[24] However, new certification standards, such as Green-e, have added criteria to ensure that purchased RECs carry an associated GHG reduction. While certified RECs are more expensive, they offer an attractive means of offsetting the University's footprint.

In order to properly manage and reduce Scope 2 emissions from electricity generation using renewable energy, accurate accounting is essential. The DCOI is currently reviewing newly proposed World Resource Institute (WRI) standards as a way to provide a unified, consistent, and transparent basis to account for electricity purchases in Duke's GHG footprint.[25] The criteria provided by the WRI are designed around existing best practices, will help ensure the overall integrity and reliability of reported results. A detailed breakdown of these criteria is available in Appendix H.[26]

When considering the use of renewable energy and RECs to achieve climate neutrality, it is important to recognize that Duke Energy is also on track to reduce its own carbon footprint. Several factors will impact the carbon intensity (MTCO2 emitted per MWh of electricity produced) of Duke Energy's generation fleet moving forward:

- North Carolina is committed to a renewable portfolio standard (RPS). This regulation requires public utilities to generate 12.5 percent of their electricity from renewable resources by 2021. As Duke Energy incorporates more renewable energy capacity into its generation portfolio, its carbon intensity will decrease
- Duke Energy continues to pursue a construction and operating licenses for two new nuclear plants: Lee Nuclear Station and Levy County Nuclear station. With no CO2 emissions, the incorporation of new nuclear plants to replace older, CO2 intensive coal plants will significant reduce carbon intensity. [27]
- In June, 2014 the EPA released its Clean Power Plan. Under the authority of the Clean Air Act section III(D), the U.S. power sector must reduce CO_2 emissions 30 percent relative to 2005 levels by 2030.[28]

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[24] National Renewable Energy Laboratory. 2012. Status and trends in the U.S. voluntary green power market (2012 data). http://www.nrel.gov/docs/fy14osti/60210.pdf

[25] World Resource Institute. 2014. GHG protocol scope 2 guidance executive summary. http://ghgprotocol.org/files/ghgp/Scope2_ExecSum_Final.pdf

[26] See Appendix H for the WRI's scope 2 quality criteria

[27] Duke Energy. 2013. Sustainability report. http://www.duke-energy.com/pdfs/2013DukeSustainabilityReport.pdf

[28] US Environmental Protection Agency. 2014. Carbon pollution emission guidelines for existing stationary sources: electric utility generating units. http://www.gpo.gov/fdsys/pkg/FR-2014-06-18/pdf/2014-13726.pdf

Taken altogether, these factors will drive down the MTCO2 emitted per MWh of electricity produced by Duke Energy. While the exact reduction numbers have yet to be released, it is certain that as the carbon intensity of Duke Energy's generation fleet decreases, the carbon footprint of the University's purchased electricity will also decrease, in turn reducing Scope 2 emissions. Consequently, over time, the impact of renewable energy and RECs on the University's carbon footprint through Scope 2 emissions reductions will diminish.

Renewable energy projects and REC purchasing offer an attractive means of advancing Duke's climate neutrality commitment. Taken together, these two options will diversify and strengthen Duke's carbon portfolio. However, both approaches present challenges that the University must carefully evaluate before moving forward.

Carbon Offsets and Voluntary Carbon Offsets Market

Duke's CAP specified that carbon offset purchase and generation to mitigate emissions should be the final approach to attaining climate neutrality after maximizing all feasible energy efficiency and renewable energy options. A GHG or carbon offset is defined by DCOI as the reduction or elimination of GHG emissions outside of Duke University's own carbon footprint[29]. This portfolio would consider the policy and cost risks associated with and co-benefits generated through various offset projects or purchases. The Campus Sustainability Committee intended for the portfolio to:

- "Generate offsets from local, Southeastern U.S. sources, including partnerships with universities with similar climate neutrality commitments;
- Pursue global carbon offsets options by capitalizing on Duke's engagement with the international research community;
- Reflect an active role in project development rather than passive purchase of offsets;
- And engage a wide range of institutions and schools with the campus."[30]

The Campus Sustainability Committee's Offsets Subcommittee has recommended that the university remains in line with the following principles in pursuing projects: pursue transportation and energy efficiency initiatives before seeking to offset emissions; find opportunities for authentic, local offsets to enhance the local green industry economy; and accumulate knowledge from early offset experiences. [31]

The CAP emphasized pilot offset projects and research as to the potential for projects in North Carolina in the methane capture, forest management and afforestation, and energy efficiency

[29] Duke Carbon Offsets Initiative. 2015. What carbon offsets are. http://sustainability.duke.edu/carbon_offsets/information.php
[30] Duke Climate Action Plan. 2009. http://sustainability.duke.edu/climate_action/Duke%20Climate%20Action%20Plan.pdf
[31] Ibid

sectors.[32] The Offsets Subcommittee of the CSC recommended that the near term strategy of Duke University should incorporate the following categories for carbon offset pilot projects: [33]

- **"Swine Waste**—Duke should explore investment in reducing GHG emissions at three hog farms using the methane capture and waste conversion technologies modeled for the Nicholas Institute by Cavanaugh & Associates[34]
- **Forest Management and Afforestation**—Duke should combine its research with practical application with forest managers, including Duke Forest, NC State forest, and land trusts
- **Energy Efficiency**—Energy efficiency could make a significant contribution to the Durham community and towards Durham's greenhouse gas commitments. Duke should suggest promoting energy efficiency in the community or amongst its employees at their homes, resulting in indirect emission reductions and significant energy cost savings."[35]

Duke has made substantial progress towards the carbon offsets goals laid out in the CAP, as illustrated in the 2013 Progress Report. In 2013 the Loyd Ray Farms swine waste-to-energy project yielded its first verified carbon offsets and in 2012 the DCOI entered into a partnership with the South Carolina Help My House energy efficiency program. This initiative helps to purchase carbon offsets that are generated by improvements to the energy efficiency of customers' homes.[36] As indicated in the 2013 Progress Report, emissions were 243,026 MtCO2e, or 28% below the 2007 baseline. This means that the amount of emissions needing to be offset has fallen.

The state of the voluntary carbon offsets market suggests a fruitful and diverse landscape for investment. The voluntary demand for carbon offsets has been growing in recent years, suggesting growing interest on the part of private companies. In 2012 voluntary participants purchased 101 $MTCO_2e$ of carbon offsets ($MtCO_2e$) for immediate or future use, representing an increase of 4% over 2011.[37] The largest share of offset purchases was contracted by the private sector, with primary motivations being corporate social responsibility and industry leadership.[38] The average price of an offset in the voluntary market per volume-weighted $/$MTCO_2e$ fell to $5.9/ $MTCO_2e$ in 2012 from $6.2/ $MTCO_2e$ in 2011.[39] Suppliers predict that the market value of carbon offsets could attain $1.6 - $2.3 billion by 2020.[40] Voluntary offset buyers' preferred project types show a priority

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[32] Duke Climate Action Plan. 2009. http://sustainability.duke.edu/climate_action/Duke%20Climate%20Action%20Plan.pdf
[33] Ibid
[34] Simmons, G. 2011. Digester systems for animal waste solids – the Lyod Ray Farms project http://www.penc.org/Files/2011/2011-Raleigh-Conference/Loyd-Farm-Presentation-12-15-2011.aspx
[35] Duke Climate Action Plan. 2009. http://sustainability.duke.edu/climate_action/Duke%20Climate%20Action%20Plan.pdf.
[36] Sustainable Duke, Office of the Executive Vice President. 2013. 2013 Progress Report. Duke's Sustainability Strategic Plan. http://www.hr.duke.edu/media/sustainability/2013SustainablitityProgressReport.pdf.
[37] Peters-Stanley, M., and Yin, D. 2013. *Maneuvering the Mosaic: State of the Voluntary Carbon Markets.* Bloomberg New Energy Finance. June 2013.
[38] Ibid
[39] Ibid
[40] Peters-Stanley, M., and Yin, D. 2013. *Maneuvering the Mosaic: State of the Voluntary Carbon Markets.* Bloomberg New Energy Finance. June 2013.

for affordable, readily available, and simple projects.[41] In 2012, the renewables category accounted for 34% of the transacted volume of project purchases with 26 million MtCO2e, with wind energy projects the most favorable. Following were forestry and land use (34%), household devices (9%), methane (9%), energy efficiency and fuel switches (8%), and gases (including ozone depleting substances and nitrous oxides) (6%).[42]

Quality of Co-Benefits Provided

Since Duke has a variety of options for attaining climate neutrality by 2024, co-benefits are used as an additional metric of evaluation in developing the final portfolio. Co-benefits are those where a project benefits the university in indirect ways, and each co-benefit displays a certain level of importance to Duke University as defined by DCOI. To determine the level to which each category of projects had the ability to meet co-benefits, a matrix was created to illustrate the qualitative magnitude of each benefit for each project in the portfolio.

A ranking of high, medium, or low for each project determined the extent to which the individual project met each of the seven broad categories. A score of four or more "high" rankings for a single project indicated a high level of overall co-benefits produced for the university. Only projects receiving four or more high (dark green) shadings out of the seven possible were included in the portfolio option for Highest Levels of Co-benefits. The matrix groups all co-benefits into seven broad categories that includes educational value, location/proximity to campus, job creation, scalability, environmental benefits, costs to Duke, and benefits to Duke.

Table 1. Co-Benefits Scorecard for Energy Efficiency Projects

		Energy Efficiency		
	Co-benefit	Lighting Retrofits	Student Behavioral Changes	Vending Miser Technology
1	Educational value	low	High	Medium
2	Location/proximity	High	High	High
3	Job Creation	low	Medium	low
	Scalability	low	low	low
4	Environmental Benefits	low	low	low
5	Costs to Duke (pricing/labor)	Medium	High	Medium
7	Benefits for Duke (PR/risk mitigation/partnerships)	Medium	High	Medium

[41] Peters-Stanley, M., and Yin, D. 2013. *Maneuvering the Mosaic: State of the Voluntary Carbon Markets.* Bloomberg New Energy Finance. June 2013.
[42] Ibid

Table 2. Co-Benefits Scorecard for Carbon Offsets Projects

		Forest Offsets		Methane Capture Offsets		
	Co-benefit	Duke-developed local projects	Purchasing from Local projects	Self-developed Projects	Purchasing from Local Projects	Purchasing from Vendors
1	Educational value	High	Low	High	Medium	Low
2	Location/proximity	High	Medium	High	Medium	Low
3	Job Creation	Medium	Medium	Medium	High	High
	Scalability			Low	Medium	High
4	Environmental Benefits	High	High	High	High	High
5	Costs to Duke (pricing/labor)	High	Medium	Low	High	High
7	Benefits for Duke (PR/risk mitigation/partnerships)	High	Medium	High	Medium	Low

Table 3. Co-Benefits Scorecard for Renewable Energy Projects

		Renewable Energy				
	Co-benefit	On-campus renewable energy	GreenSource Rider Program	Community Solar	Bass Connections	REC Purchasing
1	Educational value	High	Medium	Medium	High	Low
2	Location/proximity	High	High	High	High	Low
3	Job Creation	Low	Low	Low	Low	Low
	Scalability	Low	Medium	Low	Low	High
4	Environmental Benefits	Medium	Medium	Medium	Low	Medium
5	Costs to Duke (pricing/labor)	Low	Medium	Medium	High	Medium
7	Benefits for Duke (PR/risk mitigation/partnerships)	High	Medium	High	High	Low

Objectives of Portfolio Approach

To achieve an approximate CO_2 emission reduction of 45% by 2024 and attain climate neutrality, the DCOI is working to develop a robust portfolio of offset and emissions reduction alternatives. Projects incorporated into the portfolio include methane capture, community-based energy efficiency, forestry, land-conservation, and renewable-energy-based options. Taken altogether, these projects form the foundation for a portfolio that provides environmental, economic, and societal co-benefits at the local, state, and regional level. Moreover, implementation of these projects will provide various educational opportunities for students, faculty, and staff.

A major benefit of adopting a portfolio approach to achieve climate neutrality is that it manages risk through project diversification. Specifically, the portfolio approach accommodates for uncertainty, spreading resources across a range of opportunities and projects to ensure continual progress towards climate neutrality. By creating a strong portfolio of high integrity, unique offset and emissions reductions projects, the DCOI will be better able to adapt to the complex and ever changing carbon landscape.

In the final portfolio, we identify which mix of carbon offsets, renewable energy options, and energy efficiency will produce the lowest cost option, highest level of co-benefits, and most balanced approach for Duke University. Through the creation of three different portfolios, a variety of options are presented for Duke to consider should campus priorities shift in the future.

Potential Projects and Purchasing Options

Forestry Offsets

The forestry sector presents a multitude of opportunities to offset carbon emissions. Due to the powerful impact of forests as carbon sinks, the wide variety of projects available in the forestry sector, and the bountiful co-benefits produced by maintaining or introducing healthy forests, we project that Forestry Offsets will be a compelling component of the carbon offsets portfolio. Opportunities for forestry offsets have been divided into purchased forestry offsets and Duke-developed projects.

Purchasing forestry offsets

Several carbon offsets marketers have been contacted and opportunities for purchase have been explored. Two viable options have been selected: purchase from international vendors and purchase from regional vendors.

Forest offsets from international vendors

There are many resources available to purchase international and national forestry offsets. One innovative site that has recently been developed is "Stand for Trees," developed by Code REDD and USAID, that allows individuals to purchase unique, high-quality, verified carbon credits that protect a specific endangered forest and offset a metric to of CO_2. Certifications teams approved by Code REDD and USAID monitor the projects and help the local communities become stewards to fight deforestation, protect habitats, and bring about an economic model that values live trees over dead.[43] The tool is user friendly and easy to use. Credits from forest projects are available from multiple international locations.

- **Location:** Multiple projects are available in international locations, including:
    - Rimba Raya Orangutan Reserve, Indonesia

[43] Stand for Trees. 2015. How it works. https://standfortrees.org/en/how-it-works .

- Kasigau Wildlife Corridor Project, Kenya
  - Mai Ndombe Forest Conservation Project, Democratic Republic Of The Congo
  - Lower Zambezi Community Forest Project, Zambia
  - Amazon Forest Protection Project, Brazil
  - Chocó-Darién Forest Conservation Project, Colombia
  - Buddhist Monk Forest Conservation Project, Cambodia
  - Makira Natural Park Project, Madagascar
  - Brazilian Rosewood Forest Conservation Project, Brazil
  - Stand for Trees selects a critical forest project for you, "Express Purchase" [44]
- **Developer**: Code REDD and US AID
- **Project Area Size**: multiple sizes
- **Total issuance**: no credit limit stated on website; credits can be purchased in multiple increments
- **Approximate credit price**: \$10/$MTCO_2e$[45]
- **Registries:** Verified Carbon Standard and the Climate Community and Biodiversity Alliance
- **Protections**: Stop deforestation and protect wildlife habitat in a specific forest.[46]
- **Co-benefits:** High scalability potential; ability to generate additional offsets; air and water quality improvements; improvement of biodiversity and erosion control; Public Relations potential for Duke; little time and effort to develop or purchase; economic development and community engagement for areas in vicinity of projects (but not for Duke/Durham/regional community); educational value to students in such as provide a case study for the development of apps and website for conservation purposes or other social benefits

Blue Source

Blue Source is a carbon offset developer and marketer in North America that has been selling offsets in a number of markets since 1996. It sells offsets in a number of sectors, including but not limited to:

- Forestry
- Landfill
- Coal mine methane
- Transportation
- Waste water treatment
- Agricultural methane
- Industrial

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[44] Stand for Trees. 2015. How it works. https://standfortrees.org/en/how-it-works
[45] Ibid
[46] Ibid.

- Renewable energy
- Biomass, biogas and fuel switching

Blue Source offsets are listed in a number of major registries including the Climate Action Reserve (CAR), American Carbon Registry (ACR), Verified Carbon Standard (VCS), and Compliance Instrument Tracking System Service (CITSS).[47] Projects can be purchased in various volumes, from 150 $MTCO_2e$ to 9,000,000 $MTCO_2e$. Several contract structures are available, and offsets can be purchased from a single project or a portfolio. Questions to consider before contacting Blue Source for purchases include: the volume desired; the project type; preferred certification standards; vintage years (if any); geographic location and co-benefits desired; and start date.

After extensive communication with Josh Strauss, the Director of Forest Carbon Projects at Blue Source, the company has offered a summary of a successful project undertaken in South Carolina that can be used as a proxy for the type of project from which Duke can purchase offsets. Blue Source is considering working on a similar project in the same region of South Carolina.[48]

Blue Source: Francis Beidler Improved Forest Management Project

The Francis Beidler Forest is a valuable virgin Bald Cypress and Tupelo Gum swamp forest, one of the largest remaining in the world, with 1,000-year-old trees and native species protected in a one of a kind sanctuary.[49] The forest offers habitat to many animals including 63 species of herpetofauna (9 salamanders, 16 frogs/toads, 9 turtles, 8 lizards, 20 snakes and 1 crocodilian); 56 species of neotropical migrant birds; scores of mammals (including beaver, river otter, mink, bobcat, black wood rat, armadillo, numerous bat species and occasionally black bear); and a vast array of invertebrates. Special birds protected by the forest include: Prothonotarty, Swainson's and Kentucky Warbler; Acadian and Great-crested FlyCatcher; Wood and Hermit Thrush; and Swallow-tailed and Mississippi Kite. Streams within and around the Project Area contain many species of fish including redbreast sunfish, blue-gill sunfish, red ear sunfish, warmouth, black crappie, long-nosed gar, bowfin, striped bass, large-mouth bass and 3 catfish species. These streams connect with streams and rivers in which 60 other species from the Atlantic Ocean and its estuaries spawn. The property provides habitat that could support threatened species including Rafinesque's big eared bat, federally threatened frosted flatwoods salamander, bald eagle, federally endangered wood stork, red-cockaded woodpecker, shortnose sturgeon, pondberry, and chaffseed.[50]

- **Location:** Four Holes Swamp, South Carolina

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[47] Blue Source. 2015. Project Types. http://bluesource.com/Project-Types#sthash.dQN6yHPw.dpuf.
[48] Josh Strauss (personal communication, January 23, 2015).
[49] National Audubon Society. 2013.Beidler Forest. http://beidlerforest.audubon.org/overview-2.
[50] Josh Strauss (personal communication, January 23, 2015).

- **Client/Landowner**: The National Audubon Society
- **Project Area Size**: over 5,500 acres
- **Total issuance through 2013**: 485,267 credits
- **Approximate credit price**: \$8 - \$12/$MTCO_2e$
- **Registries:** Initially verified under CAR and then had credits for vintages 2007-2013 converted to California Compliance Credits.
- **Protections**: No harvesting is permitted.
- **Co-benefits:** air and water quality improvements; improvement of biodiversity and erosion control; public relations potential for Duke; formation of partnerships; attractive costs per offset; little time and effort to develop or purchase.

Generating forestry offsets through new projects

Several opportunities for new, Duke-developed projects in the local community have been explored by the Master's Project team. While many more projects exist than are listed here, some of the most promising opportunities have been narrowed down to two: collaboration with the Triangle Land Conservancy on easement purchases and tree plantings, and partnership with Durham Urban Forestry to aid in tree planting and maintenance in Durham.

Collaboration with Triangle Land Conservancy

Easement Projects

Founded in 1983, the Triangle Land Conservancy (TLC) is a Durham-based organization that seeks to identify, prioritize and secure the protection of areas in the Triangle region that still have high ecological or natural value.[51] Its goals are to safeguard clean water, protect wildlife habitat, keep local farms and food in the community, and provide places for people to connect with nature.[52] To achieve these objectives, TLC identifies important natural and working lands in the area and collaborates with landowners, developers, municipalities, non-profit partners, and the public to preserve ecologically important land along streams and natural areas.[53] TLC was contacted by the Masters Project team regarding the potential for partnership with Duke on easement projects in the local area. The nature of the relationship that the Duke Carbon Offsets Initiative is seeking was made clear: Duke would donate the funds to carry out projects and Duke would claim all offsets.

TLC responded with great enthusiasm and the Associate Manager of Stewardship, Matt Rutledge, provided a list of projects that are of high priority to the organization (Table 1). These are projects that Duke can implement right away. Matt expressed that additional easement projects are also available. Triangle Land Conservancy has not estimated the carbon offsets that could be generated from protecting these easements. Most of them are located on private land. Species of plants and

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[51] What We Do, Triangle Land Conservancy. http://www.triangleland.org.
[52] Ibid
[53] Ibid

animals inhabiting the easements have not been determined. Tree species are likely to be pine or hardwood.

Table 4. Triangle Land Conservancy - Highest Priority Parcels

PIN	COUNTY	Total Value (2014)	Acres	Forest Area (sq ft)	Wetland Area (sq ft)	Stream Length (ft)
0860-02-97-0539	DURHAM	$461,303	71.879	84796.1239	43053.43806	1554.844169
0860-02-85-5975	DURHAM	$359,270	50.468	193378.92	30813.27749	1073.847444
0860-04-84-4135	DURHAM	$567,985	178.657	650432.343	95194.52944	3007.177521
0860-02-67-0888	DURHAM	$815,012	176.162	442928.087	87220.78064	4063.249604
0860-04-65-3072	DURHAM	$515,350	83.07	324138.684	16999.68752	1258.861997
0850-03-92-3981	DURHAM	$459,205	93.384	370685.267	54406.48651	2059.506806
0860-02-52-5275	DURHAM	$8,770,349	216.829	752565.005	38991.62053	3582.801582

*cost to purchase an easement is approximately 50% of total value

**transaction costs for each donated easement are approximately $30,000

TLC is part of the Upper Neuse Clean Water Initiative, a coalition of nonprofits and local governments lead by the Conservation Trust for North Carolina. Its mission is to safeguard lands critical to the long-run health of drinking water supplies in the Upper Neuse River Basin.[54] The priority ranking of easement preservation projects is determined by this initiative, which aims to identify the tracts of land most critical to conserve. Considerations include:

- High quality water
- Presence of wetlands
- Proximity to Falls Lake
- High potential for development

[54] Upper Neuse Clean Water Initiative. Conservation Trust for North Carolina. 2015. http://www.ctnc.org/land-trusts/statewide-land-protection-programs/upper-neuse-clean-water-initiative/.

Projects receive financial backing from local and state government agencies, with substantial resources coming from N.C. Clean Water Management Trust Fund, the City of Raleigh, Durham County and City, Orange County, and the City of Creedmoor. One major criterion for the generation of carbon offsets is additionality. This question was addressed with Matt Rutledge, and he expressed that whatever projects are generated with the help of Duke can be considered additional. There is currently no movement on the projects provided to the DCOI Master's Project team, and there are more projects than available funding. Most of the funding sources are matching funds, meaning that the more funding Duke University can contribute, the more easements will be protected.

Tree Planting Projects

TLC also identified a few tree planting initiatives that can be undertaken in the area. They include a

1. Brumley Nature Preserve, Orange County – 22 acres. Restoration would convert old fields to mixed shortleaf pine – hardwood stands.
2. Walnut Hill Nature Preserve, Wake County – up to 80 acres. Restoration of old farm field, potentially to a longleaf pine savanna.

All Triangle Land Conservancy projects:

- **Location:** multiple sites throughout Durham County
- **Client/Landowner**: The Triangle Land Conservancy
- **Project Area Size**: 972 acres
- **Total available:** 136,656 credits
- **Approximate credit price**: \$20/ $MTCO_2e$
- **Registries:** None
- **Protections**: None
- **Co-benefits:** air and water quality improvements; improvement of biodiversity and erosion control; economic and community improvements; public relations potential for Duke; formation of partnerships; attractive costs per offset; little time and effort to develop or purchase; educational value should students utilize areas for study purposes.

City of Durham Urban Forestry

Division Manager Kevin Lilley and Urban Forestry Manager Alex Johnson at the City of Durham's Urban Forestry division indicated a number of areas where Duke University could contribute resources towards tree planting and maintenance efforts in Durham. Lilley and Johnson expressed that while there is much talk about increasing canopy in Durham, there is no corresponding increase in funding or staff for this. Urban Forestry projects are rich in potential co-benefits. Due to constraints on funding and personnel, many will not be undertaken without outside funding, contribution of volunteers and expertise. The current goal of Durham Urban Forestry is to plant 500 trees per year. Whatever Duke University could support beyond this would be valuable, additional contribution to the community.

Kevin Lilley and Alex Johnson stressed that the demands of tree maintenance and planting in Durham exceed their resource capabilities, and much more is required than is currently being performed. They expressed the goal for a complete tree inventory in Durham as well as a guidebook of criteria for when to plant trees, their point of decline, and when to replace them. Also needed is a diversification of existing species to increase health and better pruning and maintenance. Skilled forestry students could be called upon to generate an inventory and establish a guidebook, and other students could perform activities not requiring a high level of skill or equipment in the early stages. Johnson currently runs an arboriculture training to educate people about how to care for trees. Duke University could greatly increase his capabilities by calling upon forestry professionals and students to teach segments of this. On a large scale, Johnson also expressed the desire to have a local nursery of urban tolerant trees adapted to the conglomeration of soils, varied microclimates, and above and below ground limitations of the urban environment.[55] Currently, Durham Urban Forestry has to leave the state to purchase trees, and has access to a very limited number of species whose prices are rising.

While higher socio-economic communities in Durham are eager to have more trees planted to enhance the attractiveness and historic feel of the neighborhood, lower socio-economic neighborhoods exhibit less demand for more trees, further constrained by the reluctance of renters and landowner. What is sorely missing here is stakeholder engagement. Lilley and Johnson talked about community ambassadors that could educate citizens about the value of trees; notify them of opportunities to receive free and subsidized trees; and work with official neighborhood associations to find sites for new trees.

Another opportunity to generate offsets and co-benefits to the community occurs after trees have fallen. Currently, Durham Urban Forestry pays waste management companies a fee to remove trees, and there is no control over what happens to them once they are turned over. Again, this is due to resource limitations. This amounts to a waste of money for Durham that could be devoted to increased tree planting and maintenance, and a lost opportunity to generate offsets from turning tree refuse into biochar or biofuel for use in a digester. There is a company called Enviva that provides woody biomass to customers in the power generation and industrial sectors. Since 2007 it has been supplying wood chips and wood pellets to U.S. and European customers and has facilities in Mississippi, North Carolina, Virginia and Florida.[56] This is one example of a beneficial partnership that could be established between Durham and the private sector, funded by Duke and generating carbon offsets.

Analysis of Forestry Offsets

There are pros and cons to the various forestry offsets projects described above that merit consideration. Purchased offsets are the easiest to obtain and require the smallest resource

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[55] Urban Horticulture Institute, Department of Horticulture, Cornell University. 2009. Recommended Urban Trees: Site Assessment and Tree Selection for Stress Tolerance. http://www.hort.cornell.edu/uhi/outreach/recurbtree/pdfs/~recurbtrees.pdf.
[56] Enviva Biomass. 2015. About Enviva. http://www.envivabiomass.com/about/.

investment. International projects offer high co-benefits at a relatively low cost, but would be more difficult to integrate into Duke's educational curriculum for immediate study as they are far removed geographically. However, a web-platform like Stand for Trees presents educational opportunities in terms of studying how to generate an app or website for environmental or social causes. If locations could be identified close to current Duke Study Abroad programs, or if projects could form the basis of a study-abroad program, these options could also contain a direct study educational component and add more value in terms of educational co-benefits.

Offsets purchased from regional projects with Blue Source, for example, have similar co-benefits as international projects. Depending on their exact locale, Duke University might feel the effects of these co-benefits more directly. A project preserving a forest in South Carolina might not provide immediate educational, economic, or environmental co-benefits, but would enhance the health of the regional Mid-Atlantic community. Duke-developed projects are the most time and resource intensive and require the most planning. Purchasing easements and contributing to tree plantings with Triangle Land Conservancy is an attractive project due to ease of deployment. TLC has already identified the projects and they are ready for purchase in the near future. Co-benefits in the Duke-developed local offsets category are highest. For example, if a section of forest or wetland is protected within the watershed that feeds Duke University and Durham's water supply, co-benefits are considerably higher. Since TLC prioritizes easements based on their importance to the quality of water supplies in the Upper Neuse River Basin, co-benefits to the surrounding environment and community would be high. Co-benefits categories impacted could include: air and water quality improvements; improvement of biodiversity and erosion control; equity of distribution of benefits within the community; and public relations potential for Duke.

The most resource intensive project, in terms of time and money, is partnership with Durham Urban Forestry on tree plantings and tree maintenance. This project also provides the highest co-benefits, in terms of educational value to students and local communities; proximity to campus (so the offset can be managed and accessible by students and faculty); potential for job creation; increased community engagement; equity of distribution of benefits within the community; air and water quality improvements; improvement of biodiversity and erosion control; public relations potential for Duke; and formation of partnerships. A partnership with Durham Urban Forestry would also require the most planning and development, because not all the opportunities are at the stage of being immediately deployable. The scale and intensity of engagement depends on the time and resources that Duke is willing to devote to local or regional projects.

Methane Capture

Another carbon offset option that Duke University could pursue is methane capture. As the calculations show in Appendix I, burning methane to carbon dioxide would indeed reduce the total CO2 equivalent, and thus lowering the global warming impact.

For the purpose of this study, three different types of methane capture options have been examined: self-developed methane capture projects by the university, purchasing methane carbon offsets from vendors, and directly purchasing methane carbon credits from local programs.

Self-developed Methane Capture Project by Duke University

Loyd Ray Farms

In 2011, Loyd Ray Farms finished construction in Boonville, North Carolina. It is a feeder-to-finish swine farm with nine barns housing 8,640 swine.[57] The manure is flushed to a 2.1 million-gallon in-ground lined and covered anaerobic digester once each week. Biogas for electricity generation is produced in the digester. In total, approximately 400,000 gallons of waste enters the covered basin digester per week, and an estimated 50,400 cubic feet of biogas is produced each day. [58]The biogas is then piped from the anaerobic digester to a 65-kilowatt (kW) micro turbine electricity generator to be combusted. Due to the high volume of biogas production, it is possible for this project to add another additional micro turbine. The total cost of the project was $1.2 million, including all related environmental and electricity generation facilities. The farm operator did not provide any of the financial support for the system construction. Rather, the whole project was funded by several different sources including the following:

- $115,000 from the North Carolina Division of Soil and Water Conservation's Lagoon Conversion Program
- $385,000 from the United States Department of Agriculture (USDA) Natural Resources Conservation Service's (NRCS) Environmental Quality Incentives Program (EQIP), through NRCS's Cooperative Conservation Partnership Initiative (CCPI)
- $700,000 from Duke University and Duke Energy
- Maintenance expenses shared by Google, Inc. and Duke University

UNC Landfill Methane Capture Project

The University of North Carolina at Chapel Hill (UNC) partnered with Orange County, North Carolina to develop a landfill project that converts the methane gas collected from the county landfill into electricity. UNC constructed the project and owns all environmental assets associated with the destruction of methane. This includes the carbon offsets and RECs from renewable electricity generation. These carbon offsets will help the UNC campus to be climate neutral by 2050.

UNC pays the county for the landfill gas based on the price of natural gas and the quantity of gas piped. This case exemplifies how local governments and universities may collaborate for environmental benefits. The construction started from installing a gas collection and flaring system, thus landfill gas was piped from the landfill to the flaring station at the first stage of the project. UNC purchased a generator at the second stage, and the electricity produced by this 1000-kilowatt

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57 EPA, 2012. AgSTAR Loyd Ray Farms. http://www.epa.gov/outreach/agstar/projects/profiles/loydrayfarms.html
58 Ibid

power generation system is supplied to the Duke Energy grid. Additionally, the generator is located on the future Carolina North site and will provide heat to the first buildings[59].

The total project cost is $6.6 million, including the construction, design services and miscellaneous fees. Besides the initial cost, estimated annual maintenance cost is $200,000. The annual issued quantity of carbon offsets registered on Climate Action Reserve (CAR) is around 36,000 metric tons[60]. Thus, the unit cost of carbon offsets generated from this project can be converted to $15 per metric ton of carbon, based on a twenty-year lifespan.

The initial costs of Loyd Ray Farm and UNC Landfill Methane Capture Project both seem significantly higher than purchasing offsets from third parties. However, the universities' self-developed projects contribute to their social benefit in terms of educational value to students and increased community engagement.

Purchasing Offsets from Vendors

Duke University could purchase offsets from carbon offsets marketers who have been selling carbon offsets generated from multiple methane capture projects. There are many resources available to purchase methane offsets nationwide, such as Blue Source and Origin Climate.

According to the information provided by Climate Trust and Environmental Credit Corp., the average cost of carbon offsets is approximately $3 per metric ton of carbon if purchased from NC landfill projects, whereas $7-8 per metric ton of carbon from livestock digestion projects. The offset price of a specific project also depends on the vintage and registry (e.g., Chicago Climate Exchange, Climate Action Reserve). For instance, if the carbon offsets were generated from a project developed earlier, the price would be cheaper.

In general, methane captured from livestock and landfill projects can be piped to an electricity generation and flaring system. The pedagogical values of offsets purchased from methane capture projects may not be as high as self-developed projects, but the two types of projects share similar community and environmental benefits such as the elimination of odor and other volatile organic compounds in surrounding communities and improved public health. Methane projects would provide jobs, which would be helpful especially in rural communities with a high unemployment rate. Both landfill gas projects and livestock projects would improve public safety in terms of mitigating the risk of water pollution. Landfill gas capture projects prevent water pollution from the

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[59] The University of North Carolina at Chapel Hill News Archive. 2010. UNC, Orange County launch joint landfill methane gas project. http://uncnewsarchive.unc.edu/2010/11/16/unc-orange-county-launch-joint-landfill-methane-gas-project-2

[60] Rub Canyon Engineering. 2013. Verification Report-CAR917 Orange County NC Landfill Gas Project. https://thereserve2.apx.com/mymodule/reg/TabDocuments.asp?r=111&ad=Prpt&act=update&type=PRO&aProj=pub&tablename=doc&id1=917

infiltration of toxic chemicals into ground water, and livestock projects would reduce the possibilities of organisms flushed by storm water runoff.

Origin Climate Inc. is one of the vendors that provides greenhouse gas emission reduction projects for clients. Origin Climate manages all phases of carbon offset projects, from initiating and financing projects to offset sales and verification. Several carbon offsets generated from methane capture projects developed by Origin Climate are available for purchasing, and a project description is shown below as an example.

- **Project Name:** Midwestern Diary
- **Type of Project:** Livestock gas capture
- **Source of solid waste:** Cow's manure
- **Estimated credit volume:** 10,000 credits per year
- **Registration:** Climate Action Reserve (CAR)
- **Approximate credit price:** \$7-\$8 per credit
- **Co-benefits:** Air and water quality improvements; potential for job creation; little time and effort to purchase; increased community engagement

Purchasing Offsets from local facilities

Another option for Duke University for methane capture offsets would be the direct purchase from local methane capture facilities including both landfill and agricultural methane capture. Any potential facilities within the state of North Carolina are defined as local.

There are limited numbers of local landfill and agricultural methane capture projects. An example of such a project would be the Gaston County Solid Waste project located in Dallas, North Carolina. It serves as the suburb of both Charlotte and Gastonia and is approximately 180 miles from Duke University. Detailed information about this project is listed below:

- **Name of the facility:** Gaston County Solid Waste
- **Location:** Philadelphia Church Road, Dallas, North Carolina
- **Type of the project:** Single landfill methane capture
- **Source of solid waste**: Municipal solid waste, commercial solid waste, construction/demolition debris, yard waste, special wastes/sludge, wood pallets, homogenous wood pallets, shingles, low density waste
- **Estimated credit volume:** 80,000 credits per year
- **Vintage:** 2013, 2014
- **Registration:** Climate Action Reserve (CAR)
- **Approximate credit price:** \$2-\$3 per credit

Compared to purchasing credits from third party vendors, one of the major benefits is that this project provides the University a more flexible price. According to the program manager, if the University agrees to purchase the credits with Gaston County Solid Waste for a multi-year agreement then the facility would be willing to accept a lower price for each credit.

Analysis of Methane Offsets

Local methane capture projects would provide the University with more flexible prices on large-scale purchases, thus the total cost would be slightly lower. According to the program manager at Gaston County Solid Waste, if the University agrees to purchase the credits with them for a multi-year agreement then the facility would be willing to accept a lower price for each credit. However, the co-benefits of such projects are mixed depending on the type of methane capture project. If the University purchases offsets from vendors, the co-benefits would be highly compromised in terms of education value, risk mitigation and opportunities for partnerships with offset producers. On the other hand, direct purchase from local offset producer such as Gaston County Solid Waste above shares similar co-benefits with self-developed projects, including a higher educational value, better proximity and easier risk mitigation. Nonetheless, the final carbon offset price for a self-developed project is approximately three times compare to direct purchase from a facility.

Energy Efficiency Projects for Students Housing

Energy efficiency has the potential to lower the amount of carbon that will need to be offset by 2024 to reach climate neutrality[61]. Since the 2009 Climate Action Plan (CAP), Duke has taken several steps towards reducing overall emissions on campus through energy efficiency in many academic buildings. However, athletics and student housing have yet to implement or move forward with as many energy efficiency projects or retrofits when compared to academic buildings. Therefore for the energy efficiency part of this analysis, student housing was chosen as the primary focus to yield the greatest amount of carbon savings on campus (apart from those savings mentioned in Duke's CAP). Energy efficiency, and behavioral changes in particular, may be hard to verify and implement, which is a factor that must also be taken into consideration when looking at each portfolio option.

Project 1: Behavioral Changes in Campus Dorms

One of the largest potential sources to yield higher levels of energy efficiency on campus is through behavioral changes in the student. LEED certified buildings only go so far in energy conservation and the rest is often dependent on occupant behavior. Approximately ten of the dorms on East Campus were investigated to demonstrate what measures residents could improve upon in their everyday lifestyles to contribute to lowering carbon emissions. Student led groups on campus, such as the EcoReps, have already initiated preliminary efforts to improve student behavior in dorms and meet on a weekly basis to discuss sustainability efforts on East Campus[62]. Since the students volunteer time, many of the behavioral changes suggested below are low cost options that would only require basic oversight and guidance from staff. Such energy efficiency improvements would allow for the highest amount of student involvement amongst all of the energy efficiency projects. Some of the most significant energy reduction opportunities and recommended behavioral changes include:

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[61] Duke Climate Action Plan. 2009. http://sustainability.duke.edu/climate_action/Duke%20Climate%20Action%20Plan.pdf

[62] Through attendance of an EcoRep meeting in October 2014

- ***Individual Window AC units***[63]: Most units are kept on approximately 24 hours per day during the school year to regulate room temperature and air flow; AC units are one of the highest energy users in most dorm rooms consuming over 60 times more energy than a mini fridge. By incentivizing students to simply shut off AC for 12 hours per day (~50% decrease in overall usage of individual AC units), the campus could mitigate nearly 3.5 million kilowatt-hours of energy per year or almost 1,500 metric tons of carbon equivalent[64]. This would be an optimistic estimate but exemplifies the extent to which a simple alteration in habits can result in high levels of energy savings. Most students spend fewer hours in their dorm rooms per day than this so this would be a very feasible proposal. This would only be effective until central cooling was added to all campuses, which is projected to happen within the next 10 years according to Duke's Climate Action Plan[65]. However, this is a promising short-term solution in the interim. Duke's Sustainability Committee and Eco-reps could utilize their current resources in order to facilitate this process.

- ***Mini fridges***[66]***:*** A majority of students living in dorms purchase personal mini fridges in their rooms. By simply raising the temperature of the fridge by 1 degree Celsius (or 1.8 degrees F), energy consumption decreases by 2-3%. This is a simple way to conserve energy in dorms while still maintaining the quality and safety of food in the fridge.

- ***Desk lamps***[67]***:*** According to building code standards, the total lumens in each room should be more than enough to meet the minimum lighting requirements. Ultimately the goal would be to entirely phase out personal desk lamps and transition to only central lighting, which is left on all day due to consistent traffic throughout the dorms. Another option would be start an incentive program to use desk lamps less often.

- ***Communal Lighting***[68]: Currently many students do not utilize the common areas in dorms. The use of common areas with communal lighting for an additional 1 hour per day in place of the personal lighting of dorm rooms could help to further reduce campus carbon emissions.

- ***Personal Microwaves***[69]***:*** Microwaves provide another device that not only draws energy when in use but draws high quantities of energy when plugged in but not in use. By simply unplugging a microwave when not in use, energy from plug loads in dorms could be decreased. It is estimated that the average student uses their personal microwave, on

[63]Duke Facilities Management and individual student (freshmen) responses
[64] See appendix for calculations
[65] Duke Climate Action Plan. 2009. http://sustainability.duke.edu/climate_action/Duke%20Climate%20Action%20Plan.pdf
[66] Duke Facilities Management and individual student (freshmen) responses
[67] Ibid
[68] Ibid
[69] Duke Facilities Management and individual student (freshmen) responses

average, once per day or approximately three minutes. Therefore, this leaves over 23 hours of potential savings per day for plug load management which has the potential to yield over 1 million kWh of annual energy savings campus-wide. It would be recommended that the university begin to educate students and create awareness around plug load management.

- ***Phone and Computer Chargers*[70]*:*** Another easy fix in terms of plug load 4management would be encouraging student to unplug phone chargers, computer chargers and other similar devices when not in use saving the campus over 11,000 kWh of energy annually. This would decrease the energy consumption of most of these devices by about 90-95% since phones only need to be recharged for approximately an hour or less per day to reach fully capabilities.

Recommended Project: Influencing Student Behavioral Changes in Dorms on Campus. This summary provides savings when behavioral changes are extrapolated to all three campuses (East, West, and Central)

- **Annual Energy Savings**: 200,000 kWh
- **Estimated Annual Savings**: $ 1,000,000
- **Total Initial Investment:** $0
- **Annual GHG Savings (metric ton CO2e)**: 4,667[71]

- **Co-benefits**: Educational value to students and local communities, location or proximity to campus, public relations potential for Duke, quick return on investment, formation of partnerships, costs per offset, time and effort to develop or purchase

Project 2: Installation of VendingMiser Devices on Vending Machines

Duke's East Campus has over 45 Pepsi and Coke beverage vending machines located throughout both academic buildings and dorms[72]. This project involves the application of VendingMiser devices on the vending machines. The VendingMiser device can be plugged directly into the outlet with the beverage machine plug and reduces cooling energy by approximately 46%[73]. By using an occupancy sensor, the machine can detect student traffic within a certain radius of the machine and determine whether the machine needs to be fully cooled or only partially cooled. Additionally, Pepsi and Coca-Cola vendors have stated that the device does not affect product quality and have approved the device[74].

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[70] Ibid

[71] Generated by calculating total energy savings from accomplishing 100% of recommended behavioral across al three of Duke's residential campuses

[72] Visual survey conducted by Ashley Brasovan

[73] Optimum Energy Products, LTD. 2015. VendingMiser Store. http://www.vendingmiserstore.com/

[74] Optimum Energy Products, LTD. 2015. VendingMiser Store. http://www.vendingmiserstore.com/

Recommended Project: Decreasing Energy Consumption of Campus Vending Machines through the Addition of VendingMiser Devices

- **Annual Energy Savings**: 66,000 kWh
- **Estimated Annual Savings**: $ 5,000
- **Total Initial Investment:** $9,000
- **Simple Payback**: 2 years
- **Annual GHG Savings (metric ton CO2e)**: 25
- **Co-benefits**: Educational value to students and local communities, location or proximity to campus, public relations potential for Duke, quick return on investment, formation of partnerships, time and effort to develop or purchase

Project 3: Lighting Retrofits: Conversion to Lower Wattage T8 Tube Lights in Dorms on East Campus[75]

Duke is in the process of retrofitting much of the interior and exterior lighting of university and academic buildings. With the dorms being primarily managed by HDRL, only a few student-housing locations have installed occupancy sensors and more efficient lighting technology. With student traffic in undergraduate dorms occurring throughout all hours of the day, occupancy sensors are essentially useless. However, a more effective option would be a retrofit of current lighting to lower wattage T8 or T5 fluorescent tube lights or LED tube lights. Unlike occupancy sensors, a full lighting retrofit would not only guarantee energy and emissions savings but also decrease overall maintenance and operational costs in student housing. It also allows for the potential to provide higher levels of lumens in the dorms for improved student safety.

By conducting an initial inventory of East Campus to calculate the amount and types of lighting in each dorm, it was found that many of the dorms still were using the higher wattage fluorescent tube lights that were discolored and often burned out. The newest East Campus dorms (GA, Blackwell, Randolph, and Belltower) had this lighting fixture primarily in individual student dorm rooms while the older dorms had the fixture only in hallways and stairwells. Here, a complete retrofit of all T8 fluorescent tube lights to the General Electric (GE) 25W Ecolux Bulb is proposed with a rated lifetime that is four times longer than that of the current type being used on the campus[76]. After speaking with a representative from Grainger, it was determined that the lower wattage fluorescent lighting had a higher rated lifetime and a much lower price point when compared to the LED option.

Recommended Project: Retrofit of all T-8 Tube Lights in Hallways, Stairwells, and Individual Dorm Rooms to a Lower Wattage Option

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[75] Duke Facilities Management and individual student (freshmen) responses
[76] GE Lighting. 2015. Ecolux fluorescent lamps. http://www.gelighting.com/LightingWeb/na/solutions/technologies/linear-fluorescent/ecolux.jsp

- **Annual Energy Savings**: 22,000 kWh
- **Estimated Annual Savings**: $ 1,700
- **Total Initial Investment:** $7,000
- **Simple Payback**: 4 years
- **Annual GHG Savings (metric ton CO2e)**: 8
- **Co-benefits**: Educational value to students and local communities, location or proximity to campus, public Relations potential for Duke, formation of partnerships, time and effort to develop or purchase

Project 4: LED Exit Sign Retrofit Summary[77]

Most dorms on East campus (with the exception of GA, Blackwell, Randolph, and Belltower) have incandescent exit signs while newly constructed buildings have LED exit signs. There are more than 120 incandescent exit signs still remaining on Duke's East campus. At Duke's current pricing rates with Grainger, it would cost approximately $50 per sign to replace the remaining incandescent signs plus the cost of campus maintenance staff labor. This project involves a campus-wide retrofit of LED exit signs, which would lower energy usage, reduce overall operational and maintenance costs of the signs, and contribute to decreasing the campus's carbon footprint.

Recommended Project: LED exit sign retrofit

- **Annual Energy Savings**: 15,000 kWh
- **Total Initial Investment:** $8,000
- **Estimated Annual Savings**: $1,800
- **Simple Payback**: 4 year
- **Annual GHG Savings (metric ton CO2e)**: 5
- **Co-benefits**: Educational value to students and local communities, location or proximity to campus, public relations potential for Duke, formation of partnerships, time and effort to develop or purchase

Based on this analysis, focusing on lower-cost options such as student behavioral changes and the addition of energy efficiency of vending machines would make the most economical sense. Duke could lower its overall carbon footprint by almost 5,000 metric tons per year with a cost of only $0 to $360 per metric ton of carbon offset. With a much higher upfront cost and cost per metric ton of carbon offset (about $1,200 per metric ton of carbon), lighting retrofits in the dorms should be a secondary consideration for lowering the carbon emissions of the campus. With the carbon emissions factor on campus (or metric tons of CO2 emitted per kWh) being fairly low and the cost of LED bulbs being much higher than other lighting alternatives, lighting projects have a much higher capital cost with fewer fewer co-benefits than the alternative energy efficiency options. As a

[77] Duke Facilities Management and individual student (freshmen) responses

result, these projects are recommended for longer-term implementation with the immediate focus being on the behavioral changes and vending machines retrofits.

In terms of emissions reduction, the impact of implementing behavioral changes in the residential dorms on campus will cover a much larger footprint than both lighting retrofits and vending machine retrofits combined. The impact diminishes over time as the energy intensity of the electricity purchased from Duke Energy by the University decreases and as the AC units and other technology become more efficient. The exact emission reduction potential from each individual project is shown in the table below:

Table 5. Emission Reduction Potential

Project Name	Annual Electricity Savings (kWh/year)	Estimated Carbon Offsets (metric tons/year)	Estimated # of US homes annual electricity Equivalent
Lighting Retrofits	36,847	46	3
Vending Machines	65,871	82	6
Behavioral Changes (East)	3,783,241	1,419	349
Behavioral Changes (West and Central)	8,662,295	3,248	799
Total	**12,548,255**	**4,795**	**1,158**

Co-benefits associated with the development of energy efficiency on campus vary from project to project but for the most part include increased educational value to students, close proximity to campus, public relation potential for Duke, ability to form partnerships within and outside of the Duke community, and little time required for the development of projects. In addition, behavioral changes on campus offer a low cost per offset and high return on investment. The diversification of Duke's portfolio with the inclusion of some or all of the energy efficiency projects will allow Duke to more quickly meet its climate neutrality goals by lowering baseline emissions on campus.

Overall, energy efficiency projects and retrofits offer a way for Duke to meet its climate neutrality goals while maintaining a diverse portfolio when combined with renewable energy and the other offset options explored in this analysis. As prices in lighting and other larger retrofits decrease, it is recommended the Duke transition to more efficient technology on campus and re-evaluate the economic feasibility of some of these options.

Summary of All Recommendations on all Three Campuses

The summary of all recommendations for students housing retrofits and projects through three campuses is displayed as below.

- **Annual Energy Savings**: 13,000,000 kWh
- **Estimated Annual Savings**: $ 1,000,000
- **Annual GHG Savings (metric ton CO2e)**: 5,000

Renewable Energy

On Campus Renewable Energy

Of all the options available to Duke University in pursuing climate neutrality, renewable energy is the most complex and challenging. First, the generation of renewable energy should be understood as an emissions reduction to the University's carbon baseline rather than an offset. Second, despite the declining costs of renewable technologies and emergence of new financing mechanisms, developing Duke-owned renewable energy projects on campus currently does not make economic sense. Third, as the carbon intensity (MTCO2e/MWh) of electricity purchased from Duke Energy by the University decreases over time, so does the value and impact of renewable energy options.[78]

To illustrate the cost of developing renewable energy on campus, a hypothetical solar PV project was created using the National Renewable Energy Laboratory's System Advisory Model (SAM). SAM is able to predict performance and cost of energy estimates for grid-connected power projects using location, system design, system costs, financial parameters, and utility structure as specific by the user.[79] With help from Duke Facilities Management, a SAM simulation was constructed using the following inputs:

- Performance Model: Photovoltaic (PVWatts)
- Financial Model: Commercial (distributed)
- Weather: USA NC Raleigh Durham International data
- System Design
    - Nameplate Size: 701 kWdc
    - Rate Inverter Size: 637 kWac with 96% efficiency
    - Array Type: Fix open rack (tilt = 30°; azimuth = 155°)
    - Total System Losses: 14.08%
- Total Installed Cost: $3.89/Wdc[80]
- Degradation rate: 0.5%/year
- Financial Parameters (assuming Duke directly purchases and owns the system)
    - Total Installed Cost: $2.72 million
    - Financing: 100% equity
    - Nominal Discount Rate: 8.14%
    - Depreciation: none
- Incentives: none[81]
- Electricity Rates: Optional Power Service, Time of Use with Voltage Differential[82]
    - Flat buy rate: $0.0613/kWh

[78] See appendix C
[79] National Renewable Energy Laborary System Advisory Model – V2015.1.30. Downloaded from https://sam.nrel.gov/
[80] According to the US DOE Sun Shot Program median installed prices for large commercial systems (100 kW >) in 2013 was $3.89/W.
[81] Duke is a non-profit entity, and unable to directly take advantage of any state or federal solar tax credits
[82] Detailed rate schedule available at http://www.duke-energy.com/pdfs/NCScheduleOPTV.pdf

- Fixed monthly charge: $32.17/month
- Annual Electricity Cost Escalation: 2%/year
- Net metering: none[83]

- Analysis Period: 25 years

Running SAM using the inputs specified above produces the following results, displayed in the table below.

Table 6. On-Campus Renewables Financial Analysis

Metric	Value
Annual Energy Production	980.9 MWh
Capacity Factor	16.0%
Initial Cost	$2,727,507
Levelized Cost (real)	$209/MWh
Net Savings with System	$207,998
Net Present Value	-$504,480
Payback Period	15.0

Based on this analysis, installing a Duke-owned solar PV system on campus currently does not make economic sense. Even when using an ideal installed cost of $3.11/W – the lowest quoted cost for Duke to date – the net present value of a modeled system is still -$7,700 with a payback period of 12.1 years.[84] Interestingly, this installed cost is close to the net present value break-even point of $3.09/W. If Duke is able to leverage installed costs equal to or lower than this break-even point in the future, on-campus renewable energy will be economically feasible.

From an emissions reduction standpoint, the impact of a 701 kW system on Duke's carbon baseline is relatively low. This impact diminishes over time as the carbon intensity of electricity purchased from Duke Energy by the University decreases. The exact emission reduction potential based on the annual generation projection from the SAM analysis above is shown in the table below

[83] If Duke University were to operate under the net metering rider, it must surrender any RECs generated by the solar PV system to Duke Energy, and would not be able to claim any emissions reductions. Additionally, installing the additional infrastructure necessary to net meter would add significant capital costs to any proposed project.

[84] This is confirmed by Duke Facilities Management, which has evaluated the potential for on-campus renewable energy multiple times since the release of the 2009 Climate Action Plan.

Table 7. Potential Emission Reductions through On-Campus Renewables

Year	Emissions Reductions (MTCO2e)
2015	461
2024	284
2032	199
2040	132

Co-benefits associated with developing renewable energy on campus are mixed. On a positive note, a project located on campus will provide valuable educational opportunities for staff and students. Moreover, the diversification of Duke's energy portfolio will provide a unique PR opportunity that can distinguish Duke from its peers. Unfortunately, the cost to Duke would be high ($2.72 million). Additionally, once completed, projects are not scalable, but would lend valuable insight to the construction of any future projects.

Overall, on campus renewable energy projects, such as solar PV, offer a unique means for Duke to diversify its energy portfolio as the University works to achieve climate neutrality. However, such projects are complex, and come with significant costs and challenges that must be carefully addressed by the University before moving forward. Ultimately, as the cost of renewable energy technologies continues to decline and policies such as the EPA's Clean Power Plan are implemented, it is strongly recommended that Duke continue to evaluate the potential of on-campus renewable energy, and pursue such options if they become economically viable.

Green Source Rider program with Duke Energy

An alternative option for Duke University to pursue renewable energy on campus is the Green Source Rider program through Duke Energy. Implemented in 2013, the Green Source Rider offers energy intensive, non-residential customers the option of offsetting their energy consumption from newly established load with renewable energy.[85] To be eligible for the program, customer must have added at least 1 MW of new demand to their total energy purchases since June 30, 2012.

Under the Green Source Rider program, the University would continue to purchase electricity under its current rate structure. However, Duke Energy will modify the University's Electric Service Agreement to include the cost of any renewable energy or renewable energy credits purchased through the program. This charge will depend on the amount renewable energy that is to be procured or produced on behalf of Duke University. The University will also be billed an administrative charge of $500 per month and $0.0002 per kWh of renewable energy purchased

[85] Duke Energy Carolinas. 2013. Duke Energy Carolina's Petition for Approval of Rider GS (Green Source Rider) Pilot Docket No. E-7, Sub 1043. http://www.duke-energy.com/pdfs/2013111501-addendum.pdf

during a billing period.[86] Essentially, the University will be entering into a fixed Power Purchase Agreement with Duke Energy for a specific amount of renewable energy delivered each month for a certain number of years.

According to the program description, the University would also

> receive a bill credit for renewable energy produced or procured, determined by applying an "all-in" avoided energy and capacity ¢/kWh rate to the actual renewable kWh procured or produced. This bill credit is intended to be equal to the avoided capacity and energy expense experienced during the term in which the renewable energy supplier delivers renewable energy to Duke Energy or Duke Energy supplies renewable energy to [the University]. This value of this credit is determined at the discretion of Duke Energy, though [the University] will be allowed to review the proposed credit prior to electing to participate in the program.[87]

As of February 2015, Duke University is evaluating a proposal to install 701 kW of solar PV on campus through the Green Source Rider program. Under the terms of the proposal, Duke University would engage in a 15-year power purchase agreement to buy renewable energy from Duke Energy for $0.1269/kWh. This price is $0.0656/kWh greater than what the University currently pays for electricity, but would go towards financing the construction of the solar PV project on campus.

Once constructed, the system is expected to generate roughly 913 MWh of renewable electricity annually. The associated emission reduction potential over time is shown in the table below.

Table 8. Potential Emission Reductions through GreenSource Rider Program

Year	Emissions Reductions (MTCO2e)
2015	429
2024	265
2032	185
2040	123

Co-benefits associated with developing renewable energy through the Green Source Rider program are high. This project would be located on campus, and renewable energy purchasing could be scaled beyond the annual generation of the system. Moreover, like a University owned project, a Green Source funded PV project will provide a unique PR opportunity that can distinguish Duke from its peers. However, while the costs would be lower than a Duke owned on-campus project, the

[86] Duke Energy Carolinas. 2013. Duke Energy Carolina's Petition for Approval of Rider GS (Green Source Rider) Pilot Docket No. E-7, Sub 1043. http://www.duke-energy.com/pdfs/2013111501-addendum.pdf

[87] Ibid

educational opportunities will not be as valuable; because Duke would not own the panels, its students and faculty may not have the same level of access.

Overall, the Green Source Rider program represents a unique opportunity for Duke to diversify its energy portfolio while offering significant co-benefits. Because Duke would not need to directly buy and own the panels, it removes much of the cost and risk associated with the previous PV project discussed while offering similar emission reductions. As such, it is strongly recommended that the University work to implement a mutually beneficial contract with Duke Energy through the Green Source Rider program.

Community Solar

An alternative option for Duke to develop renewable energy project is community solar. Specifically, community solar refers to a PV installation owned by multiple stakeholders that provides power or financial benefit those stakeholders.[88] Unlike an on-campus solar PV project, Duke can utilize a community solar PV system installed offsite and benefit from its output remotely to reduce its emissions baseline. Compared to an identical project on campus, community solar would generate similar emission reductions at similar costs.

Installing an off-campus solar system can offer several advantages compared to projects that are limited by on-campus restrictions. These benefits include:

- Optimal siting that maximizes power production by avoiding shading or structural concerns
- Mitigating potential issues with building codes or aesthetic concerns
- Expanding participation to include other local universities that have similar climate neutrality goals

The co-benefits of a community solar project are mixed. From a positive standpoint, the major benefit is the opportunity to partner with other University's to diversify Duke's energy portfolio. Such a partnership would create a valuable PR opportunity that can distinguish Duke as a leader in environmental stewardship. Additionally, the project would likely be cited close to campus, providing educational value to both students and local communities. From a negative standpoint, the cost of a community solar will be high compared to other offset options, and require significant time and effort to develop. Moreover, once completed, the system could not be scaled to generate additional offsets, but would lend valuable insight to the construction of any future projects..

While community solar is an interesting option for Duke University, it comes with significant complexity and challenges. Any proposed project must address the legal and financial challenges of setting up a special purpose entity to own and operate the system, as well as comply with securities

[88] Coughlin, J. 2010. A guide to community solar: utility, private, and non-profit project development. National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy11osti/49930.pdf

regulation.[89] The project must also negotiate a contract between the site host, participants, and utility. These contracts are necessary to outline the legal and financial processes for sharing benefits, and establish the management structure for the operation of the special purpose entity.[90]

Overall, community solar offers a unique opportunity to diversify Duke's energy portfolio. However, given the challenges associated with developing such a project, it is recommended that the University conduct a more thorough analysis beyond the scope of this report. Still, it is anticipated the community solar will be a viable option for Duke in the future as renewable energy costs continue to decline. Based on this projection, community solar is included as a potential project in the portfolio assessment.

REC Purchasing

As of 2014, indirect Scope 2 emissions from purchased electricity account for 43% of the Duke's total carbon footprint[91]. On this basis, it is clear that RECs offer significant value in advancing the University's climate neutrality commitment as they can be applied to offset Scope 2 carbon emissions. However, buying RECs to mitigate emissions from purchased electricity is not a new concept. The Nicholas School, Fuqua, and Pratt have purchased RECs in the past to offset energy usage. Moreover, on a national level, total retail sales of voluntary RECs in 2012 alone exceeded 48 million MWh across nearly 1.9 million customers.[92] Given the high demand for RECs, a number of RECs products are now available to customers, giving Duke the opportunity to choose from a variety of suppliers.

As **Table 9** shows, RECs offer a lower price on average compared to the renewable energy options discussed in previous sections. There are several reasons for this difference:[93]

- RECs are not restricted by geography and as such can utilize the least expensive renewable resources
- REC suppliers are not required to meet a purchaser's electricity needs
- Because REC suppliers do not deliver any power to the REC purchaser, costs associated with power generation and distribution are avoided
- RECs are fungible in a voluntary market, and thus prices reflect greater competition

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[89] Coughlin, J. 2010. A guide to community solar: utility, private, and non-profit project development. National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy11osti/49930.pdf
[90] Ibid
[91] Sustainable Duke. 2014. Greenhouse gas inventory. http://sustainability.duke.edu/climate_action/inventory.php
[92] National Renewable Energy Laboratory. 2012. Status and trends in the U.S. voluntary green power market (2012 data). http://www.nrel.gov/docs/
[93] United States Environmental Protection Agency. 2014. Environmental value of purchasing RECS. http://www.epa.gov/greenpower/rec.htm

Table 9. REC Purchasing Options

Source	Type Available*	Location	Certification	REC Price
3Degrees	B, G, H, M, S, W	Nationwide	Green-e	$10
3 Phases Renewables	G, H, M, S, W	Nationwide	Green-e	$12
Arcadia Power	W	Nationwide	---	$15
Bonneville Environmental Foundation	H, S, W	Nationwide	---	$20
Carbon Solutions Group	B, H, M, S, W	Nationwide	Green-e	$5
Community Energy	W	Nationwide	Green-e	$25
EDP Renewables	W	Nationwide	---	$8
GP Renewables & Trading LLC	H, L, M	Localized	---	$2
GoodEnergy	S, W	Nationwide	Green-e	$50
GoodEnergy	S	Southeast	Green-e	$200
Green Mountain Energy Company	H, S, W	Nationwide and regional	Green-e	$14
Mass Energy Consumers Alliance	W	New England	---	$50
NC Green Power	H, L, M, S, W	North Carolina		$40
North America Power	W	Nationwide	Green-e	$15
Pear-Energy	W	Midwest	---	$15
Renewable Choice Energy	W	Nationwide	Green-e	$20
REpowerNow	H, S, W	Wisconsin	---	$25
Santee Cooper	L, S	South Carolina	Green-e	$30
Sky Energy, INC.	W	Nationwide	---	$24
Sterling Planet	W	Nationwide	Green-e	$19
TVA: Mountain Electric Cooperative	L, S, W	North Carolina	Green-e	$27
Waverly Light & Power	W	Iowa	---	$20
WindCurrent	W	Mid-Atlantic States	---	$25
WindStreet Energy	W	Nationwide	---	$12
Average Price: $28/REC **Average Price (certified):** $36/REC **Average Price (Uncertified):** $20/REC				

*Note: B = Biogas; G - Geothermal; H = Hydro; L = Landfill Gas; M = Biomass; S = Solar; W = Wind

Differences between REC products also impact price. On average, certified RECs command a much higher price than uncertified RECs. New certification standards, such as Green-e, have added additionality criteria to ensure that purchased RECs carry an associated GHG reduction. While certified RECs are more expensive, they offer a more reliable means of offsetting the University's footprint. REC price also vary by state and technology, as the various markets respond to their specific RPS requirements. Overall, the co-benefits associated with REC purchasing are poor. While the cost and scalability of REC purchasing relative to other renewable energy options is favorable, the education value and PR co-benefits are low. Locational co-benefits depend on where the RECs were generated. While Duke could purchase nationally sourced RECs, the administration has clearly stated that only locally sourced RECs will be considered.[94]

The value of RECs as a carbon offset mechanism will also decrease over time. As Duke Energy incorporates more renewable energy capacity into its generation portfolio, the amount of carbon produced per unit of electricity generated will decrease. In turn, the carbon footprint of the University's purchased electricity will also decrease. Thus, in a given year, the University will have to purchase more RECs to offset the same amount of carbon as the previous year.[95]

Ultimately, the quantity and price of RECs purchased by Duke will depend on the standards set by the University. Importantly, Duke should only purchase certified RECs in order to avoid any concern about the quality and impact of the purchase. Before moving forward with any purchases, it is recommended that Duke engage with leading REC suppliers and industry experts to establish and communicate clear standards for any University-based purchase. The World Resource Institute standards, for example, offer a good starting point, and will help to ensure the overall integrity and reliability of any REC purchases.

Bass Connections in Energy

Established in fall 2013, Bass Connections is "a new university-wide initiative that links faculty and students to respond to complex challenges through problem-focused educational pathways and project teams."[96] One of the five thematic areas of this program is energy. Each Bass Connections in Energy project team focuses on a particular energy challenge related to the economy, environment, and/or security.

Several of the challenges faced by Duke University in advancing its climate neutrality commitment align strongly with the Bass Connections effort, and more importantly, demand collaborative solutions from teams whose members come from diverse backgrounds and experiences. Past and present project teams have explored a number of topics ranging from energy efficiency, system design and innovation, the smart grid, and distributed generation.

One project in particular, Distributed Solar Generation for Duke University Employees, focuses on expanding Duke's renewable energy portfolio. Over the course of Fall 2014 and Spring 2015, the project team is exploring opportunities that will enable Duke employees to purchase and install solar for their homes[97]. By providing access to quality information, discounted installation prices, and attractive financing options, the project will provide a valuable employee program that furthers Duke's climate neutrality commitment.

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[94] From personal correspondence with Duke Facilities Management
[95] See appendix C for Scope 2 emissions reduction potential over time
[96] Duke University. 2015. Bass Connections. https://bassconnections.duke.edu/
[97] One of the authors of this report, Ellis Baehr, is also on the Bass Connections project team described.

According to the projects website, the team is expected to achieve four major objectives:

1. "Educate the Duke employee community on residential solar to empower employees to make informed decisions regarding whether solar energy is right for them.
2. Engage the Duke community in a coordinated and consistent manner to provide online and in-person educational tools that will inform employees about residential solar installation options.
3. Provide Duke employees access to affordable residential solar through trusted local installers.
4. Establish a pipeline of local renewable energy projects that can be tracked in terms of renewable energy production and avoided greenhouse gas emissions to establish a steady stream of carbon offsets to help Duke University meet its climate neutrality commitment, thereby achieving the University's mission of attaining climate neutrality through local and economically beneficial projects."[98]

Even if only a few employees install solar, the program will be considered a success; however, past community campaigns have resulted in dozens of installations. While the impact in terms of emissions reductions will depend on the total amount of solar installed, the co-benefits are significant, including:

- "Significant reduction in solar installation cost for Duke employees
- Environmental leadership and emission reductions for Duke University
- Community-wide engagement and mobilization
- Replicable model for future programs and at other universities
- Positive PR for Duke University and Sustainable Duke
- Employee and student educational co-benefits"[99]

In addition to the Distributed Solar Generation project, the DCOI has also proposed a feasibility study for a campus digester for fall 2015 through spring 2016. In fiscal year 2014, Duke University and the School of Medicine produced over 1,900 tons of compostable waste, the majority of which went to landfills. Rather than dispose of this waste, it can be used to feed an anaerobic digester and produce methane. This methane, as described in pervious sections, can be used as an alternative fuel and produce carbon offsets. Integrating this technology into the University's waste management system poses significant challenges, which the proposed project aims to identify and address.[100]

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[98] It is important to note that while this information is posted on http://sustainability.duke.edu/carbon_offsets/solar/, Ellis Baehr is the original author of this text.
[99] Ibid
[100] Bass Connections in Energy. 2015. Feasibility study for a campus digester. https://bassconnections.duke.edu/project-teams/feasibility-study-campus-digester

The Distributed Solar Generation project, along with the proposed Campus Digester Feasibility Study and other Bass Connections in Energy projects, offer a unique means of advancing Duke's climate neutrality commitment. Moreover, these projects are based on campus, and offer significant co-benefits to the University, students, employees, and community at little to no cost to Duke. As such it is strongly recommended that Duke continue to support and develop project teams through the Bass Connections in Energy program that address specific challenges identified in the 2009 Climate Action Plan.

Discussion of Portfolio Recommendations

In developing a diverse portfolio that would provide Duke University with options should campus priorities shift, three offset scenarios were analyzed. Modeled scenarios include a low-cost approach, a high co-benefits approach, and a balanced approach that factors in both cost and potential production of co-benefits. For each scenario, two portfolios were created: one for 2024 and one for 2040. This approach is intended to demonstrate how Duke's carbon offsets portfolio will change over time as a result of a decreasing carbon footprint. It is also important to note that the total cost and average cost per offset are given in annual terms. Moreover, while Duke-developed projects will generate offsets or emissions reductions on a continual basis, offset or renewable energy purchases would only be good for one year of use.

In all three scenarios, it is assumed that the each of the proposed project types will achieve the desired level of carbon offsets or emissions reductions. Realistically achieving each projection is not guaranteed. For example, energy efficiency behavioral changes are difficult to institute. Similarly, annual generation for proposed solar PV systems may not meet estimations. If the amount of carbon offsets or emissions projections are not achieved for a given project type, other projects will need to reconcile the difference. As a result, the total cost and average cost of the portfolio would change.

Scenario 1: Cheapest

The first approach for Duke University to develop solutions meeting the climate neutrality goal is using the price line (**Figure 2**, **Figure 3**)as a guideline to compare the different combinations of energy efficiency programs, renewable energy programs and carbon-offset options in terms of the cost.

Figure 2. Price line for expected offset costs in 2024 ($/MTCO2e)

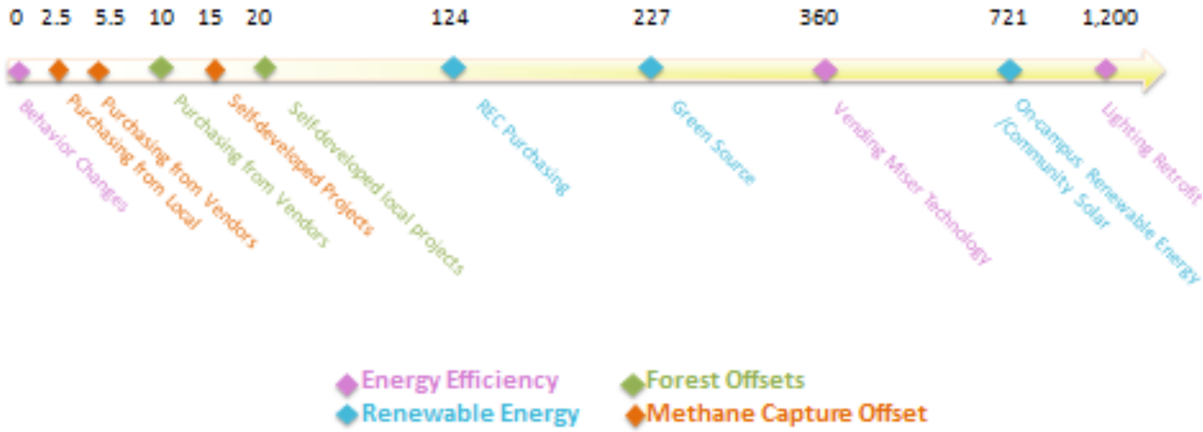
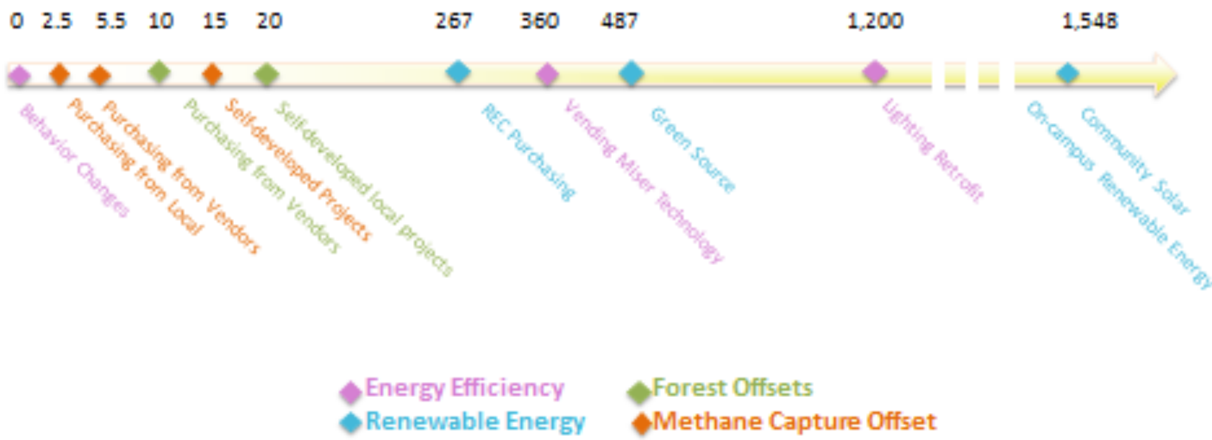


Figure 3. Price line for expected offset costs in 2040 ($/MTCO2e)



Both for 2024 and 2040, the costs of carbon offset, renewable energy and energy efficiency projects were listed on the price lines from the lowest to highest. The projects with the cheapest prices were selected for the portfolio to meet the demand for offsetting the projected carbon emissions at Duke Campus in 2024 and then again in 2040.

Therefore, three projects were incorporated into the cheapest scenario:

1. **Energy Efficiency through Behavioral Changes on Campus.**
2. **Purchasing Methane Capture Offsets from Local Projects.** Carbon offsets could be directly purchased from local landfill gas capture and livestock digestion projects. Any potential facilities within the state of North Carolina are defined as local.
3. **Purchasing Methane Capture Offsets from Vendors.** We could purchase offsets from carbon offsets marketers who have been selling carbon offsets generated from multiple methane-capture projects. Many resources are available to purchase methane offsets nationwide, such as Blue Source and Origin Climate.

These three projects are stacked in ascending order by price, i.e., energy efficiency through behavioral changes on campus at \$0/ton, purchasing methane capture offsets at \$2.5/$MTCO_2e$ from local landfill facilities and purchasing methane capture offsets from vendors at \$5.5/$MTCO_2e$. An estimated 197,543 metric tons will need to be offset by 2024, thus, purchasing methane capture offsets from vendors would provide the highest marginal cost among these three projects. Student behavioral change would offset 4,700 metric tons of carbon. Meanwhile, purchasing methane capture offsets from local projects would generate 80,000 metric tons. Purchasing methane capture offsets from vendors would offset 112,843 metric tons of carbon, which is also the greatest contributor to meet the climate neutrality goal in this case. This approach corresponds to a total cost of \$820,639 and average offset cost of \$4.15/ $MTCO_2e$.

Since the anticipated 2040 carbon emission offsets are less than that for 2024, the portfolio needs to be slightly adjusted. With an estimated 135,222 metric tons of carbon needing to be offset by 2040, the quantity of methane capture offsets purchased from vendors would drop to 50,522 metric tons. However, energy efficiency through student behavioral change would still offset 4,700 metric tons of carbon. Purchasing methane capture projects from local projects would offset the same amount of carbon emissions as in 2024, i.e. 80,000 metric tons. The combined projects would yield a total cost of \$477,870 and average offset cost of \$3.53/ $MTCO_2e$.

The cheapest scenario shows that Duke University could achieve climate neutrality at a quite low cost if it wanted to, but it would lack co-benefits. With an optimistic estimate of 4,700 metric tons, student engagement would be one of the largest potential sources contributing to carbon emission reductions. However, habits are not easily altered through students' awareness and staffs' guidance. School-wide reminders are not able to guarantee that students will be willing to change their lifestyle and remember to shut down AC units and desk lamps when they leave dorms. Moreover, the total carbon emission avoided by student behavioral change on campus was maximized in this scenario, which might need to be adjusted in post-implementation analysis. If the behavior change goal could be achieved by 50%, the average cost of the portfolio would increase to \$4.21/$MTCO_2e$. Even more, if the desired amount of behavior change only be reached 25%, purchasing more methane offsets would drive the average cost of the portfolio up to \$4.25/$MTCO_2e$.

Since local methane capture projects would provide the University more flexible prices on large-scale purchase, the total cost of this scenario could decrease slightly. However, the co-benefits of purchasing offsets from vendors would be highly compromised in terms of education value, proximity and the opportunities for partnerships. Due to the heavy reality on purchasing offsets, it is necessary to verify the qualities of methane capture offsets purchased from vendors and local projects by a third party.

Table 10. Cheapest Scenario

		2024	2040
Emissions	**Projected Carbon Footprint to be Offset Based on CAP (MTCO2e)**	197,543	135,222
	Projected Carbon Intensity (MTCO2e/MWh)	0.290	0.135
Efficiency	**Total Emissions Reductions Achieved through Efficiency (MTCO2e)**	4,700	4,700
	-Lighting Retrofits	0	0
	-Student Behavioral Changes	4,700	4,700
	-Vending Miser Technology	0	0
	Total Cost of Efficiency Measures ($)	$0	$0
	-Lighting Retrofits	$0	$0
	-Student Behavioral Changes	$0	$0
	-Vending Miser Technology	$0	$0
Carbon Offsets	**Number of Offsets Generated (MTCO2e)**	0	0
	-Forestry	0	0
	-Methane Capture	0	0
	Total Cost of Offset Projects ($)	$0	$0
	-Forestry	$0	$0
	-Methane Capture	$0	$0
	Number of Offsets Purchased (MTCO2e)	192,843	130,522
	-Foresty	0	0
	-Local Projects (methane capture)	80,000	80,000
	-Vendors (methane capture)	112,843	50,522
	Total Cost of Offsets Purchased ($)	$820,639	$477,870
	-Forestry	$0	$0
	-Local Projects (methane capture)	$200,000	$200,000
	-Vendors (methane capture)	$620,639	$277,870
Renewable Energy	**Number of RECs Generated (MWh)**	0	0
	-On Campus	0	0
	-Green Source Rider	0	0
	-Community Solar	0	0
	Total Carbon Offset (MTCO2e)	0	0
	-On Campus	0	0
	-Green Source Rider	0	0
	-Community Solar	0	0
	Total Cost of Generated RECs ($)	$0	$0
	-On Campus	$0	$0
	-Green Source Rider	$0	$0
	-Community Solar	$0	$0
	Number of RECs Purchased (MWh)	0	0
	Total Carbon Offset (MTCO2e)	0	0
	Total Cost of RECs Purchased ($)	$0	$0
Summary	**Total Carbon Offset (MTCO2e)**	197,543	135,222
	Total Cost of Climate Neutrality ($)	$820,639	$477,870
	Average Cost of Climate Neutrality ($/MTCO2e)	$4.15	$3.53

Scenario 2: Greatest Co-Benefits

Using the co-benefit scorecard as a guideline, a third portfolio option for the purchase and development of carbon offsets at Duke University examined the different mixes of carbon-offset options, renewable energy, and energy efficiency that would maximize co-benefits for Duke University in 2024 and in 2040. Offset and efficiency projects scoring a "high" on at least four of the listed categories on the co-benefit scorecard were included in this portfolio approach. The Bass Connections project for renewable energy was the only exception to this since the project currently does not have any offsets associated with it.

Therefore a total of four projects met the criteria for inclusion into the highest co-benefit scenario:

1. Energy efficiency through Behavioral Changes on Campus
2. Duke-developed Forest Offsets
3. Duke-developed Methane Capture Offsets
4. Non-local Purchase of Methane Capture Offsets

Since an estimated 198,000 metric ton of carbon will need to be offset by 2024 with a projected carbon intensity of 0.29 MTCO2e/MWh, inclusion of all four projects was critical to meeting DCOI's projections and maintaining a diversified portfolio. Energy efficiency through behavioral changes on campus will offset approximately 4,700 metric tons of carbon in 2024. Duke-developed and generated projects equate to 128,562 metric tons of carbon with methane capture projects offsetting about 64,281 metric tons of that figure or approximately half of the total number of offsets generated. Developed forestry projects fill the other 64,281 offsets from Duke developed projects. Purchased methane capture projects will offset about 64,281 metric tons of carbon. All four projects combined would equate to the total amount of projected carbon that needs to be offset by 2024. This approach yields a total cost of $2,591,173 and average offset cost of $13.12 per metric ton of carbon equivalent in order to obtain climate neutrality.

With only an estimated 135,000 metric tons of carbon needing to be offset by 2040 with a projected carbon intensity of 0.14 MTCO2e/MWh, the highest co-benefit analysis shifts only slightly. Energy efficiency through behavioral changes on campus still encompasses about 4,700 metric tons of carbon. Duke-developed and generated projects will only amount to 87,015 metric tons of carbon by 2040. The Duke generated projects are split evenly with both Duke-developed forestry a methane projects each offsetting 43,507 metric tons of carbon. Purchased methane capture projects will also only need to offset about 43,507 metric tons of carbon by 2040. Purchased methane has high levels of co-benefits, since the low price of the offset qualifies as a co-benefit. This figure is lower than that of 2024 since the overall level of carbon on campus needing to be offset is inherently lower with a lower emissions factor and higher levels of energy efficient buildings and technology on campus. All four projects combined would equate to the total amount of carbon that would need to be offset by 2040 with a total cost of $1,753,776 and average cost of $12.97 per metric ton of carbon equivalent offset which is a slightly lower average cost per offset than in 2024.

When considering the highest co-benefit option in the portfolio, certain measures should be taken into consideration prior to the purchase of any offset. This includes a reevaluation of campus priorities and the overall current state of energy efficiency and renewable energy on campus and in surrounding communities. This option presents an opportunity to yield the most significant co-benefits of any one approach with potential co-benefits including but not limited to: high levels of educational value, proximity to campus, potential for job creation, scalability, environmental benefits, low costs to Duke in terms of labor and offset pricing, campus PR, risk mitigation, and high potential for partnerships. Additionally, the cost of this third portfolio approach decreases as the price of carbon decreases and is projected to have a lower average cost per offset by 2040 when compared to 2024.

Table 11. Greatest Co-Benefits Scenario

Emissions	**Year of Analysis**	2024	2040
	Projected Carbon Footprint to be Offset Based on CAP (MTCO2e)	197,543	135,222
	Projected Carbon Intensity (MTCO2e/MWh)	0.290	0.135
Efficiency	**Total Emissions Reductions Achieved through Efficiency (MTCO2e)**	4,700	4,700
	-Lighting Retrofits	0	0
	-Student Behavioral Changes	4,700	4,700
	-Vending Miser Technology	0	0
	Total Cost of Efficiency Measures ($)	$0	$0
	-Lighting Retrofits	$0	$0
	-Student Behavioral Changes	$0	$0
	-Vending Miser Technology	$0	$0
Carbon Offsets	**Number of Offsets Generated (MTCO2e)**	128,562	87,015
	-Forestry	64,281	43,507
	-Methane Capture	64,281	43,507
	Total Cost of Offset Projects ($)	$2,237,626	$1,514,488
	-Forestry	$1,273,409	$861,879
	-Methane Capture	$964,217	$652,609
	Number of Offsets Purchased (MTCO2e)	64,281	43,507
	-Foresty	0	0
	-Local Projects (methane capture)	0	0
	-Vendors (methane capture)	64,281	43,507
	Total Cost of Offsets Purchased ($)	$353,546	$239,289
	-Forestry	$0	$0
	-Local Projects (methane capture)	$0	$0
	-Vendors (methane capture)	$353,546	$239,289
Renewable Energy	**Number of RECs Generated (MWh)**	0	0
	-On Campus	0	0
	-Green Source Rider	0	0
	-Community Solar	0	0
	Total Carbon Offset (MTCO2e)	0	0
	-On Campus	0	0
	-Green Source Rider	0	0
	-Community Solar	0	0
	Total Cost of Generated RECs ($)	$0	$0
	-On Campus	$0	$0
	-Green Source Rider	$0	$0
	-Community Solar	$0	$0
	Number of RECs Purchased (MWh)	0	0
	Total Carbon Offset (MTCO2e)	0	0
	Total Cost of RECs Purchased ($)	$0	$0
Summary	**Total Carbon Offset (MTCO2e)**	197,543	135,222
	Total Cost of Climate Neutrality ($)	$2,591,173	$1,753,776
	Average Cost of Climate Neutrality ($/MTCO2e)	$13.12	$12.97

Scenario 3: Balanced

The second portfolio option takes a balanced approach to offsetting the University's carbon footprint. Using both the price line and co-benefits score card as a guide, this approach diversifies Duke's efforts towards achieving climate neutrality by including numerous options that are low-cost and/or offer significant co-benefits.[101] The combination of these options is intended to minimize cost in a way that also maximizes co-benefits.

Overall, nine options were identified as part of the balanced portfolio scenario, complementing each other in a way provides both affordability and high co-benefits:

1. Energy efficiency through behavioral change
2. Duke-developed Forest Offsets
3. Forest offsets purchased from local vendors
4. Duke-developed methane capture offsets
5. Methane capture offsets purchased from local projects
6. On-campus renewable energy
7. Green Source Rider renewable energy
8. Community solar renewable energy
9. REC purchasing

The resulting portfolio for 2024 and 2040 is shown on the following page. Between 2024 and 2040, the composition of the offset profile changes slightly. Because Duke's carbon footprint will decrease by roughly 60,000 MTCO2e over that time frame, the total number of offsets required will also decrease. This change is addressed by stepping down the purchasing of cheap, low co-benefit methane and forestry offsets in favor of Duke developed projects. Thus while the total cost of climate neutrality decreases from 2024 to 2040, the average cost per offset increases. Moreover, the carbon emissions factor from purchased electricity will decrease from 0.29 to 0.14, reducing the impact of renewable energy projects on Scope 2 emissions.

Realistically, the balanced portfolio approach is most similar to the one that Duke will likely implement. By incorporating a variety of projects, this option balances cost and co-benefits in a way that diversifies the University's approach to climate neutrality. Importantly, the portfolio approach accounts for uncertainty and spreads resources across a range of opportunities and projects to ensure continual progress towards climate neutrality. Additionally, this approach places a high priority on Duke developed forestry, methane capture, and renewable energy projects. Doing such will not only provide a long-term source of carbon offsets for the University, but will also strengthen its position as a leader in environmental stewardship and education. Ultimately, the composition of the balanced portfolio is most subject to change, as the number, variety, and

[101] See appendix D and F

scale of projects depend on Duke's priorities as well as the overall state of energy efficiency and renewable energy.

Table 12. Balanced Scenario

Emissions	**Year of Analysis**	2024	2040
	Projected Carbon Footprint to be Offset Based on CAP (MTCO2e)	197,543	135,222
	Projected Carbon Intensity (MTCO2e/MWh)	0.290	0.135
Efficiency	**Total Emissions Reductions Achieved through Efficiency (MTCO2e)**	4,700	4,700
	-Lighting Retrofits	0	0
	-Student Behavioral Changes	4,700	4,700
	-Vending Miser Technology	0	0
	Total Cost of Efficiency Measures ($)	$0	$0
	-Lighting Retrofits	$0	$0
	-Student Behavioral Changes	$0	$0
	-Vending Miser Technology	$0	$0
Carbon Offsets	**Number of Offsets Generated (MTCO2e)**	76,000	76,000
	-Forestry	40,000	40,000
	-Methane Capture	36,000	36,000
	Total Cost of Offset Projects ($)	$1,332,400	$1,332,400
	-Forestry	$792,400	$792,400
	-Methane Capture	$540,000	$540,000
	Number of Offsets Purchased (MTCO2e)	112,960	54,064
	-Forestry	32,960	14,064
	-Local Projects (methane capture)	80,000	40,000
	-Vendors (methane capture)	0	0
	Total Cost of Offsets Purchased ($)	$529,600	$240,640
	-Forestry	$329,600	$140,640
	-Local Projects (methane capture)	$200,000	$100,000
	-Vendors (methane capture)	$0	$0
Renewable Energy	**Number of RECs Generated (MWh)**	3,392	3,392
	-On Campus	995	995
	-Green Source Rider	1,402	1,402
	-Community Solar	995	995
	Total Carbon Offset (MTCO2e)	984	458
	-On Campus	289	134
	-Green Source Rider	406	189
	-Community Solar	289	134
	Total Cost of Generated RECs ($)	$508,472	$508,472
	-On Campus	$207,983	$207,983
	-Green Source Rider	$92,506	$92,506
	-Community Solar	$207,983	$207,983
	Number of RECs Purchased (MWh)	10,000	0
	Total Carbon Offset (MTCO2e)	2,900	0
	Total Cost of RECs Purchased ($)	$360,000	$0
Summary	**Total Carbon Offset (MTCO2e)**	197,544	135,222
	Total Cost of Climate Neutrality ($)	$2,730,472	$2,081,512
	Average Cost of Climate Neutrality ($/MTCO2e)	$13.82	$15.39

Summary of the Cheapest, Greatest Co-Benefits and Balanced Portfolio Scenarios

The three portfolio scenarios discussed provide Duke University with a diversity of options. It is important to reiterate that for each portfolio, total cost and average cost per offset are given in annual terms. While Duke-developed projects will generate offsets or emissions reductions on a continual basis, offset or renewable energy purchases would need to be repeated each year. Moreover, it is assumed that the each of the proposed project types will achieve the desired level of carbon offsets or emissions reductions. However, achieving each projection is not guaranteed. If the amount of carbon offsets or emissions projections are not achieved for a given project type, other projects will need to reconcile the difference. As a result, the total cost and average cost of the portfolio would change.

In all three portfolio scenarios, exit sign lighting retrofits, Vending Miser technology, and Bass Connections were not included. The exit sign retrofits and Vending Miser technology were both too expensive and lacked significant co-benefits. The Bass Connections in Energy projects, while affordable and high in co-benefits, have yet to produce any quantifiable emissions reductions or offsets.

Of the three portfolio scenarios presented, the balanced portfolio approach has the greatest diversity of project types, and is the only one that includes renewable energy options. Consequently, the inclusion of renewable energy in the balanced portfolio causes it to have the highest cost. Despite the increased cost, the balanced portfolio approach is most similar to the one that Duke will likely implement. By incorporating a variety of projects, this option balances cost and co-benefits in a way that diversifies the University's approach to climate neutrality. While the cheapest scenario shows that Duke could achieve climate neutrality at a quite low cost, it lacks co-benefits. Additionally, the high co-benefit scenario presents a strong mix of local, state, and regional environmental, economic, and societal co-benefits, but lacks project diversity. Overall, the balanced portfolio approach best accommodates for uncertainty by spreading resources across a range of opportunities and projects to ensure continual progress towards climate neutrality

Sensitivity Considerations

Several developments may influence the recommended projects presented to DCOI and the relative attractiveness of different options. In the interest of guiding the DCOI's consideration of future offset and REC purchases, as well as on campus efficiency and renewable energy measures, several major categories of interest to the Client have been analyzed. Potential influences on the composition of the portfolio include: a price on carbon, changes to the Renewable Portfolio Standard, changes in the cost of renewable energy, behavioral changes on campus, and changes in the cost of electricity.

Price on Carbon

Federal and state policy changes could affect the demand for and therefore the price of carbon offsets. Most importantly, a price on carbon would push businesses to directly decrease their CO2 emissions as well as at least partially offset remaining CO2 emissions. The group Resource for the Future explains that "a carbon tax would result in higher prices for carbon-intensive goods and services, potentially rewarding innovation and investment in renewable energy, energy efficiency, carbon sequestration, and other technologies."[102] Recent congressional attempts to introduce a carbon tax include: Reps. Bob Inglis and Jeff Flake's Raise Wages, Cut Carbon Act of 2009 (H.R. 2380 of the 111th Congress), Reps. Pete Stark and John Larson's Save Our Climate Act of 2009 (H.R. 2380 of the 111th Congress), Rep. Jim McDermott's Managed Carbon Price Act of 2012 (H.R. 6338 of the 112th Congress), and Sens. Bernie Sanders and Barbara Boxer's Climate Protection Act of 2013 (S. 332 of the 113th).[103] Given the recent change of parties in the Senate, it seems unlikely that a carbon tax will pass in the next four years.

Another possibility is a cap-and-trade scheme, which would similarly spur the demand for renewable electricity generation and carbon offsets. There is currently no such legislation, and attempts to pass it have been defeated. The latest attempt was the Waxman-Markey comprehensive energy bill, the "American Clean Energy And Security Act of 2009" (ACES) introduced into the House of Representatives.[104] This included a cap-and-trade global warming reduction plan with a goal to reduce economy-wide greenhouse gas emissions 17 percent by 2020.[105] Other provisions included new renewable requirements for utilities, studies and incentives regarding new carbon capture and sequestration technologies, energy efficiency incentives for homes and buildings, and grants for green jobs.[106] The bill was approved by the House of Representatives but defeated by the Senate.[107]

More recently, in June 2014 the EPA proposed the Clean Power Plan, which would put the first-even national limits on carbon emissions from existing power plants under Section 111(d) of the Clean Air Act.[108] These standards would cut carbon emissions from the power sector by 30 percent from 2005 levels by assigning state-specific emissions goals.[109] Each state would have four options to lower carbon pollution: make fossil fuel power plants more efficient; use low-emitting power

[102] Center for Energy and Climate Economics. 2015. Considering a Carbon Tax: Frequently Asked Questions. http://www.rff.org/centers/energy_and_climate_economics/Pages/Carbon_Tax_FAQs.aspx#Q8.
[103] Center for Climate and Energy Solutions. 2013. Options and Considerations for a Federal Carbon Tax. http://www.c2es.org/publications/options-considerations-federal-carbon-tax.
[104] OpenCongress. 2009. H.R.2454 - American Clean Energy And Security Act of 2009. https://www.opencongress.org/bill/111-h2454/actions_votes.
[105] Ibid
[106] Ibid
[107] Ibid
[108] U.S. Environmental Protection Agency. 2014. Fact Sheet: Clean Power Plan Framework. http://www2.epa.gov/carbon-pollution-standards/fact-sheet-clean-power-plan-framework.
[109] Ibid

sources more; use more zero- and low-emitting power sources; use electricity more efficiently.[110] The Plan gives states the option to convert rate-based goals to a mass-based goal if they choose, which would allow a group of states to cap their tonnage of CO_2 emissions and set up a trading option.[111] Thus, the Plan might lead to additional regional cap and trade systems like the existing Regional Greenhouse Gas Initiative. Should this occur, demand for renewable generation and carbon offsets will likely increase as more public and private entities seek to decrease their carbon emissions. A price on carbon would also cause electricity prices to rise, due to the extra charge put on the emissions of carbon dioxide through fossil fuel based electricity generation. This would further increase the financial attractiveness of renewable generation and energy efficiency improvements. These changes will take place soon, as the EPA set a goal to finalize the proposed Clean Power Plan by the summer of 2015.[112] However, due to the contentious nature of the rule, a final decision could be delayed by years of litigation in courts. Thus, uncertainty is considerable.

A future price on carbon, whether at the state or Federal level, would change the portfolio recommendations dramatically in multiple ways and is a development that the Duke Carbon Offsets Initiative should track diligently. The cheapest portfolio would be affected because purchased carbon offsets would be more expensive, and might no longer be cost effective for the University. Carbon offsets vendors would likely experience more demand for their products. Even local, Duke-developed carbon offsets projects might become more attractive to outside parties and become developed by corporate actors. The energy efficiency aspect of the cheapest portfolio would become even more persuasive with a rising cost of electricity. The highest co-benefits portfolio would likely remain the same, as a price on carbon affects the price of carbon offsets rather than the co-benefits they provide. It would, however, mean that the highest co-benefits portfolio would come at a greater cost, as it includes Duke-developed forest and methane capture offsets, and the non-local purchase of methane capture offsets. The balanced portfolio would be affected inasmuch that certain projects would become more expensive. Co-benefits would not rise due to a price on carbon, and Duke-developed forest offsets would become more attractive to outside parties and could potentially be exploited before Duke has the opportunity to establish a relationship with the providers. All purchased offsets would also become more expensive as demand in the market grows. However, the balanced portfolio also contains three renewable energy components: on-campus renewable energy, the Green Source Rider for renewable energy, and community solar renewable energy. Investment in renewable energy on campus will be a significant advantage if there is to be a future price on carbon, because it mitigates the risk of changing energy prices and balances a potential rise in carbon offsets prices. Thus, with a potential price on carbon looming on the horizon, considering renewable energy on campus is a wise strategy. The ramifications of

[110] U.S. Environmental Protection Agency. 2014. Fact Sheet: Clean Power Plan Framework. http://www2.epa.gov/carbon-pollution-standards/fact-sheet-clean-power-plan-framework.
[111] Ibid
[112] U.S. Environmental Protection Agency. 2015. Clean Power Plan Proposed Rule. http://www2.epa.gov/carbon-pollution-standards/clean-power-plan-proposed-rule.

changes in the cost of electricity for the portfolios are explored further in the Changes in the Cost of Electricity section below.

Changing Cost of Renewable Energy

Renewables are strong in North Carolina and are likely to experience future growth. The North Carolina renewables landscape is dominated by solar, accompanied by a few new biogas and waste energy installations.[113] According to the NC Sustainable Energy Association 2014 Clean Energy Industry Census, 1,200 clean energy firms are participating in the state's economy, and there has been a 15% per year increase in revenues generated by the clean energy industry since 2012.[114] Presently, NC ranks 4th in the nation for solar installations with over 600 MW of available capacity.[115] Regarding future growth, over 30% of firms in the solar, wind, fuel cells, and alternative fuel vehicles sectors anticipated employment growth in 2015. Firms report that the Southeast region is a good location for the clean energy industry and anticipate it will remain so over the next 5 years.[116] Major influences on renewable development within North Carolina, aside from the state of the technology and the attractiveness of the business environment, will include the Renewable Energy and Energy Efficiency Portfolio Standard and the Renewable Energy Investment Tax Credit.[117]

Lower prices for renewable energy will not affect the cheapest or highest co-benefits portfolios, as they have no such components. They will, however, affect four components of the balanced portfolio: on-campus renewable energy, green Source Rider renewable energy, community solar renewable energy, and REC purchases. Falling prices for renewable energy will make on-campus renewable energy and community solar cheaper, and would decrease the prices of renewable installations implemented through the Green Source Rider program. Conversely, rising prices for renewable generation would decrease the attractiveness of these components. Should prices for renewable generation fall, more renewable generators will enter the market and RECs will also become cheaper and more abundant. This will make them a more attractive component of the portfolios, and the DCOI will have greater ability to purchase a larger volume of RECs.

It is also important to keep track of developments regarding North Carolina policy on third-party solar sales. Currently, the state does not allow non-utility owners of a solar facility to sell electricity directly to a retail customer.[118] However, there is a bill in North Carolina House of Representatives

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[113] American Council on Renewable Energy. 2014. Renewable Energy in North Carolina. http://www.acore.org/files/pdfs/states/NorthCarolina.pdf.

[114] North Carolina Clean Energy Industry Census, 2014. NC Sustainable Energy Association. http://c.ymcdn.com/sites/energync.site-ym.com/resource/resmgr/Docs/2014census.pdf

[115] Ibid

[116] Ibid

[117] Ibid

[118] Frequently Asked Questions, North Carolina. Duke Energy. http://www.duke-energy.com/pdfs/FAQs_10.21.pdf

called the Energy Freedom Act that would legalize third party sales.[119] Should it pass, the barriers to solar investment would go down, as the upfront costs of purchasing a system would be broken down into monthly payments. This would decrease the costs and risks of solar energy on campus for Duke University, and it would serve the DCOI well to reassess the renewable energy options presented in this analysis.

Renewable Portfolio Standard

North Carolina has had a Renewable Energy and Energy Efficiency Portfolio Standard (REPS) since 2007. Per this policy, investor-owned utilities are required to supply 12.5% of 2020 retail electricity sales from eligible energy resources by 2021.[120] Municipal utilities and cooperatives are subject to a target of 10% renewables by 2018.[121] Eligible resources include: solar-electric, solar thermal, wind, hydropower up to 10 megawatts, ocean current or wave energy, biomass that uses Best Available Control Technology (BACT) for air emissions, landfill gas, combined heat and power (CHP) using waste heat from renewables, hydrogen derived from renewables, and electricity demand reduction. [122] A maximum of 25% of the requirement may be met through energy efficiency technologies, rising to 40% in 2021.[123] In 2011, electricity demand reduction was included as a means of achieving the REPS standard, indicating that electricity demand reduction is capable of meeting up to 100% of a utility's renewable energy requirement under the law, and is defined as "a measurable reduction in the electricity demand of a retail electric customer that is voluntary, under the real-time control of both the electric power supplier and the retail electric customer, and measured in real time, using two-way communications devices that communicate on the basis of standards."[124] While politically under attack, efforts to repeal the REPS were defeated in 2013.[125] Although unlikely, a federal Renewable Portfolio Standard might affect renewable generation in the state, depending on if it is more or less stringent than the NC RPS, and whether or not it overrides state policy.

Impacts to the REPS standard, whether it be repealed or made more stringent, will change the attractiveness of the energy efficiency, RECs, and renewable energy components of the portfolios. Regarding the cheapest, balanced, and highest co-benefits portfolios, they will be affected insomuch as behavioral changes through energy efficiency on campus are the first recommended projects in all three. If energy efficiency initiatives are encouraged at the federal or state levels, Duke Energy will likely seek more ways to encourage energy efficient behavior on the part of its consumers,

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[119] In NC, Everyone Can Win with Third-Party Sales of Electricity. North Carolina Sustainable Energy Association. March 2015. http://www.energync.org/blogpost/1249845/211404/In-NC-Everyone-Can-Win-with-Third-Party-Sales-of-Electricity
[120] North Carolina Clean Energy Industry Census, 2014. NC Sustainable Energy Association. http://c.ymcdn.com/sites/energync.site-ym.com/resource/resmgr/Docs/2014census.pdf
[121] Ibid
[122] Ibid
[123] Ibid
[124] Ibid
[125] Renewable Energy in North Carolina. American Council on Renewable Energy. January 2014. http://www.acore.org/files/pdfs/states/NorthCarolina.pdf.

which includes Duke University. Duke might therefore pursue more aggressive measures to decrease energy usage on campus, through behavioral changes and more energy efficient practices in lighting and infrastructure, making the number one project across all portfolios more attainable and freeing up resources to pursue other projects.

The components of the balanced portfolio related to renewables and RECs will also be affected: on-campus renewable energy, Green Source Rider renewable energy, community solar renewable energy, and REC purchasing. A more stringent or national RPS/REPS would incent renewable generation in the state, making projects in on-campus renewable energy, community solar, and the Green Source Rider program more technically and financially feasible and therefore cheaper and more attractive for DCOI. In the presence of a stronger RPS/REPS, demand for RECs will be also higher. In the short term, if there is not enough renewable generation to satisfy demand, REC prices might go up, making them less competitive in the portfolios. In the longer run, higher REC prices will signal the market to install more renewable capacity, and if enough is installed REC prices will go down, making them more competitive in the portfolios.[126] The price will depend on the balance between available supply and demand.

Behavioral Changes on Duke University's Campus

Behavioral changes are notoriously difficult to predict and control. Should behavioral changes exceed predictions and energy efficiency improvements on campus progress quicker than expected, baseline emissions will fall and the required number of offsets will decrease. This would be the easiest way of achieving the goal of climate neutrality by 2024. There is reason to believe that awareness of energy usage and more sustainable practices is growing among the undergraduate student body and behavioral changes will indeed decrease baseline campus emissions. An Energy and Environment Certificate for undergraduates was added in Fall 2008. Engagement in student initiatives has become more apparent as well with clubs like Students for Sustainable Living; Campus Sustainability Fellows, Dorm Eco-Reps; and the Environmental Alliance. As the DCOI becomes a more prominent presence on campus closer to the 2024 deadline, and more opportunities to engage graduate and undergraduate students into its efforts become available, those interested in energy, environment, and sustainability will be able to participate directly in DCOI projects. This could be through independent study, Bass Connections, applications in classes, and Masters Projects examining improvements to campus efficiency and reducing energy usage.

Energy efficiency through behavioral changes on campus is the first recommended project in all three portfolios (cheapest, balanced, and highest co-benefits). While theoretically the easiest to attain, it is difficult to plan for and expect a concrete set of results because of the unpredictable human component. If behavioral changes can decrease baseline emissions, all three portfolios will be favorably affected. It will be easier to devote resources to the latter, more expensive components

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[126] Environmental Value of Purchasing RECs. United States Environmental Protection Agency. April 2014. http://www.epa.gov/greenpower/rec.htm

of the portfolios, such as offsets purchases and renewable energy on campus. Conversely, if behavioral change leads to increased baseline emissions, the portfolios will be negatively affected. Duke will have to turn to more expensive measures to offsets its emissions, such as offsets, renewable energy, and RECs.

Changes in Cost of Electricity

Changes in the cost of electricity have multiple, complex repercussions for the portfolio options. Currently, Duke assumes a 3% annual growth rate in electricity cost.[127] The price of natural gas and potential GHG reduction policies will be an important determinant of the price of electricity, and one that is notoriously difficult to predict. Given the historic volatility in the price of natural gas, this will remain an unpredictable influence on the cost of electricity and the makeup of the portfolios. Generally speaking, the more expensive natural gas, the higher the cost of electricity. Should the costs of electricity rise at a rate greater than expected due to rising levelized cost of electricity of traditional fossil fuel sources, electricity generation from renewables will become more favorable for a utility. More renewable electricity generators can be expected to enter the market, and more RECs will become available for purchase. The RECs component of the balanced portfolio will be impacted, as falling prices for RECs would make them a more attractive option.

Renewables become more favorable when the cost of electricity goes up, because the payback periods for renewables projects become shorter. This will impact the balanced portfolio, which includes on-campus renewable energy, Green Source Rider renewable energy, and community solar renewable energy. Renewables on-campus and in the community will be cheaper to pursue and the costs of purchased renewables through the Green Source Rider program will be lower.

Should the price of electricity increase at a rate greater than expected, upgrades to lighting and building infrastructure will likely proceed at a faster pace as well. Rising electricity costs will increase the incentive for improved energy management and energy efficiency as a cost savings measure. This will encourage the University to upgrade lighting and equipment and find new ways to educate students on energy efficient practices and create incentives for them to decrease their energy usage. This will affect all three portfolios as the number one recommended project in each is energy efficiency through behavioral changes on campus. If electricity costs go up, Duke will decrease energy use and encourage energy efficient practices on the part of its students, lowering baseline emissions and leaving more leeway to pursue the remaining, more expensive components of the portfolios.

[127] Personal conversation with Casey Collins of Duke Facilities Management

Conclusion

Project categories excluded from portfolios

While the proposed projects in the portfolio have covered every single category in the carbon management hierarchy, there are additional available offsets projects that were not included. For example, coalmine methane capture, carbon capture sequestration (CCS) and ozone depleting substance were excluded from the portfolios. These types of projects were not optimal for Duke University due to various factors. With coalbed methane capture as an example, there are several reasons why the DCOI Masters Project team recommends Duke not consider this type of project. First of all, the availability of such projects is very limited. According to the EPA, as of 2008, there were 9,294 active coalmines in the United Sates, of which only 50 had methane capture projects.[128] Of all the carbon offset vendors the team had reached out to, only a few provided coalbed methane capture projects. In addition to the limited number of coalmines, legal issues, high capital costs for equipment, and uncertainty regarding coalbed methane ownership are among the other reasons the DCOI MP team did not include coalbed methane capture in the portfolio. Further more, CCS projects are not included because Duke does not have its own power plant or industrial processing facilities. In nearly all cases, this technology is only used for emissions produced from fossil fuel electricity generation and industrial processes. Even if the University had a power plant on campus, the capital costs of CCS would be very high and good geological sequestration sites are not available in NC. According to the International Energy Agency, it costs approximately \$693 and \$593 per kw for a gas-fired power plant and a coal-fired power to add a carbon capture system.[129] With that being said, the cost of carbon abatement per ton ranges from \$23 to \$112. The DCOI MP team did not include the Ozone Depleting Substances (ODS) offsets projects because the volume of such credits is fairly small and the projects are usually not that well-developed compared to the other options included in the portfolio.

Obstacles

Throughout the process of research and compilation of portfolios, the Masters Project team has accumulated several useful recommendations for future DCOI work. In terms of obstacles encountered, data collection and extrapolation of data were the two major concerns when analyzing energy efficiency projects and retrofits. Accessing the dorms on campus and meeting with employees in RLHS led to numerous obstacles, but these were overcome after a period of time. All energy efficiency calculations were extrapolated from a few data observations and therefore may not be completely accurate due to the lack of time to individually count each light bulb or vending machine throughout all three campuses.

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[128] Congressional Research Service, 2011 *Methane Capture: Options for Greenhouse Gas Emission Reduction.* http://fas.org/sgp/crs/misc/R40813.pdf

[129] Bibbins, J. and Chalmbers, H. 2008. *Carbon Capture and Storage*, Energy Policy, Volume 36, Issue 12.

Given the continued decline or costs and policy uncertainty surrounding renewable energy, it was difficult to produce an accurate representation of the expected price of renewable energy in 2024 and 2040. Instead, current prices were used, which may have caused the newer renewable energy options to seem relatively inflated compared to more established offset and efficiency projects. It would be unsurprising if by 2024, renewable energy is just as cost-effective, if not more so, compared to current options.

Similar issues exist with carbon offsets. Purchasing offsets is unproblematic, but although current markets suggest a robust carbon offsets landscape into the future, prices are highly dependent on policy and the private and public sectors' perceptions of the need to offset carbon emissions. A limited amount of information can be gleaned from current prices. Projects developed in the local area in partnership with non-profit groups or local government are also unpredictable due to the uncertainty of interacting with organization's changing agendas and capabilities. Establishing these partnerships is resource intensive as well.

Future work

As for future work in energy efficiency, greater energy efficiency in athletic buildings, the consolidation of practices and training room usage, and the addition of occupancy sensors in the locker rooms and training facilities could yield high carbon savings. Some other recommendations for Duke University to consider for improving energy efficiency on campus would be the addition of occupancy sensors in dorms, better computer power management in labs, and continuation of the expansion of the Employee Residential Energy Efficiency Program. In order to keep the work done on energy efficiency projects current, the DCOI should continue to look into the most efficient lighting technology on an annual basis to determine whether this option becomes more financially feasible. Additionally, the DCOI can ensure that all new technology and equipment purchased for RLHS is Energy Star certified or the most efficient on the market. Finally, the DCOI needs to continue to work with Duke's Sustainability committee, the Eco-Reps, and other student sustainability clubs and classes on campus to ensure that the Duke student body maintains adequate knowledge around energy efficiency and energy conservation on campus. This will assist in continuing to lower baseline emissions on campus in hopes of obtaining as much of the potential savings from behavioral changes as possible.

It will be necessary to reevaluate the renewable energy, efficiency, and offset landscape every five years leading up to the 2024 deadline. Picking a few project types and conducting a more detailed financial analysis that reflects the NPV and payback period of projects would provide more nuanced information and guidance. Using the existing sensitivity analysis and adding or updating projects will provide a useful starting point.

As for carbon offsets and Duke developed projects, in general, Durham city government and local nonprofits seemed highly receptive to partnering with Duke on carbon offsets projects. However, they did not know where to begin or had so many demands that it was difficult to determine what was feasible. There exists, however, a wealth of opportunity in the community for small carbon offsets projects. Strong management and a dedicated team are necessary to develop and direct these projects as establishing initial partnerships is time intensive. This is to be expected, and although engaging with the community presents new obstacles, it is a valuable and rewarding way to establish rich relationships that will benefit Duke and Durham for years to come.

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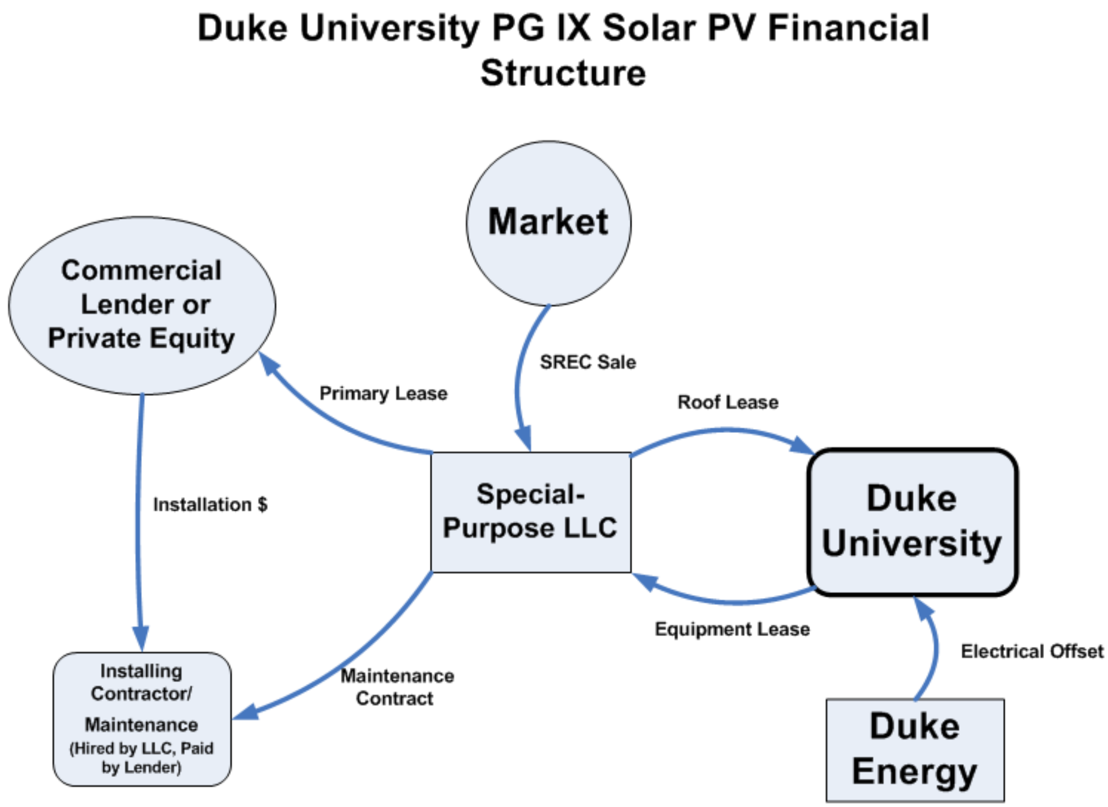
Appendix

Appendix A. Financial information used in energy efficiency calculations

Financial Inputs		**Additional Notes**
Cost of Electricity ($/kWh)	$0.074	**Figure given by Casey Collins, Duke's Energy Manager
Annual Growth Rate in Electricity Cost	3.00%	**Figure given by Casey Collins, Duke's Energy Manager
Monthly Demand Charge ($/kW)	$0	
Tax Rate	0%	*Duke is a non-profit entity and doesn't pay taxes*
Discount Rate	5.50%	**Figure given by Casey Collins, Duke's Energy Manager
GHG Emissions Information		
Location (eGrid Sub-Region emissions factor)	0.827	**Figure given by Casey Collins, Duke's Energy Manager
OR		1MTCO2 =2,204.6 lbs
Custom Emissions Factor (lbs CO_2/kWh)	0.827	**Figure given by Casey Collins, Duke's Energy Manager

Appendix B: lease buy-back arrangement for solar PV systems



Appendix C. Electricity Usage and Associated Scope 2 Emissions

Electricity Usage and Associated Scope 2 Emissions					
Year	**Projected Electricity Purchases (MWh)**	**Maximum Number of RECs Applicable (1 REC = 1 MWh)**	**Projected Carbon Intensity (MTCO2e/MWh)**	**RECs Needed to Offset 1 MTCO2e**	**Scope 2 Emissions Reduction (MTCO2e)**
2014	337,575,788	337,575,788	0.48	2.08	162,036,378
2015	336,148,715	336,148,715	0.47	2.13	157,989,896
2016	334,721,641	334,721,641	0.47	2.13	157,319,171
2017	333,294,567	333,294,567	0.47	2.13	156,648,447
2018	331,867,494	331,867,494	0.38	2.63	126,109,648
2019	330,440,420	330,440,420	0.29	3.45	95,827,722
2020	329,013,347	329,013,347	0.28	3.57	92,123,737
2021	327,586,273	327,586,273	0.28	3.57	91,724,156
2022	326,159,200	326,159,200	0.28	3.57	91,324,576
2023	324,732,126	324,732,126	0.29	3.45	94,172,317
2024	323,305,052	323,305,052	0.290	3.45	93,758,465
2025	321,877,979	321,877,979	0.300	3.33	96,563,394
2026	320,450,905	320,450,905	0.310	3.23	99,339,781
2027	319,023,832	319,023,832	0.310	3.23	98,897,388
2028	317,596,758	317,596,758	0.310	3.23	98,454,995
2029	316,169,685	316,169,685	0.265	3.77	83,784,966
2030	314,742,611	314,742,611	0.220	4.55	69,243,374
2031	316,100,651	316,100,651	0.212	4.73	66,855,288
2032	317,458,691	317,458,691	0.203	4.93	64,444,114
2033	318,816,731	318,816,731	0.195	5.14	62,009,854
2034	320,174,771	320,174,771	0.186	5.38	59,552,507
2035	321,532,811	321,532,811	0.178	5.63	57,072,074
2036	322,890,850	322,890,850	0.169	5.92	54,568,554
2037	324,248,890	324,248,890	0.161	6.23	52,041,947
2038	325,606,930	325,606,930	0.152	6.58	49,492,253
2039	326,964,970	326,964,970	0.144	6.97	46,919,473
2040	328,323,010	328,323,010	0.135	7.41	44,323,606

Appendix D. Co-Benefits Scorecards for DCOI Offset Projects

Scorecard for DCOI Offset Project
Co-benefits

		Renewable Energy				
	Co-benefit	On-campus renewable energy	GreenSource Rider Program	Community Solar	Bass Connections	REC Purchasing
1	Educational value	High	Medium	Medium	High	Low
2	Location/proximity	High	High	High	High	Low
3	Job Creation	Low	Low	Low	Low	Low
	Scalability	Low	Medium	Low	Low	High
4	Environmental Benefits	Medium	Medium	Medium	Low	Medium
5	Costs to Duke (pricing/labor)	Low	Medium	Medium	High	Medium
7	Benefits for Duke (PR/risk mitigation/partnerships)	High	Medium	High	High	Low

		Energy Efficiency		
	Co-benefit	Lighting Retrofits	Student Behavioral Changes	Vending Miser Technology
1	Educational value	low	High	Medium
2	Location/proximity	High	High	High
3	Job Creation	low	Medium	low
	Scalability	low	low	low
4	Environmental Benefits	low	low	low
5	Costs to Duke (pricing/labor)	Medium	High	Medium
7	Benefits for Duke (PR/risk mitigation/partnerships)	Medium	High	Medium

		Forest Offsets		Methane Capture Offsets		
	Co-benefit	Duke-developed local projects	Purchasing from Local projects	Self-developed Projects	Purchasing from Local Projects	Purchasing from Vendors
1	Educational value	High	Low	High	Medium	Low
2	Location/proximity	High	Medium	High	Medium	Low
3	Job Creation	Medium	Medium	Medium	High	High
	Scalability			Low	Medium	High
4	Environmental Benefits	High	High	High	High	High
5	Costs to Duke (pricing/labor)	High	Medium	Low	High	High
7	Benefits for Duke (PR/risk mitigation/partnerships)	High	Medium	High	Medium	Low

Appendix E. Other Universities Efforts

Since the initiation of the ACUPCC, signatory institutions have established various carbon offsets and energy efficiency programs to reduce their campus carbon footprint. Due to the voluntary nature of the ACUPCC, universities usually adopt different scopes and time frames for climate neutrality. Among the first signatories in 2007, the University of North Carolina (UNC)-Chapel Hill adopted the UNC system-wide sustainability policy targeting carbon neutrality by 2050. If the University achieves its target reductions, the first milestone of the program to reduce carbon emission to a year 2000 level would be accomplished by 2020[130]. Other universities in the UNC system such as Appalachian State University (ASU) has adopted the same neutrality goal but with different phases. The university has broken up the carbon neutrality plan into a 3-phase period for a 40-year time frame, 2010-2015, 2015-2025, and 2025-2050. In the current period of the program, ASU faces financial constraints on capital investment and initial carbon-offset purchases[131]. Lowering baseline emissions is generally the first approach that a university will utilize prior to the purchase of carbon offsets. This allows for a campus to reduce its total carbon footprint in the most permanent ways possible; nevertheless, depending on the levelized cost of the different abatement strategies, carbon offset might become one of the most effective options for a long-term strategy.

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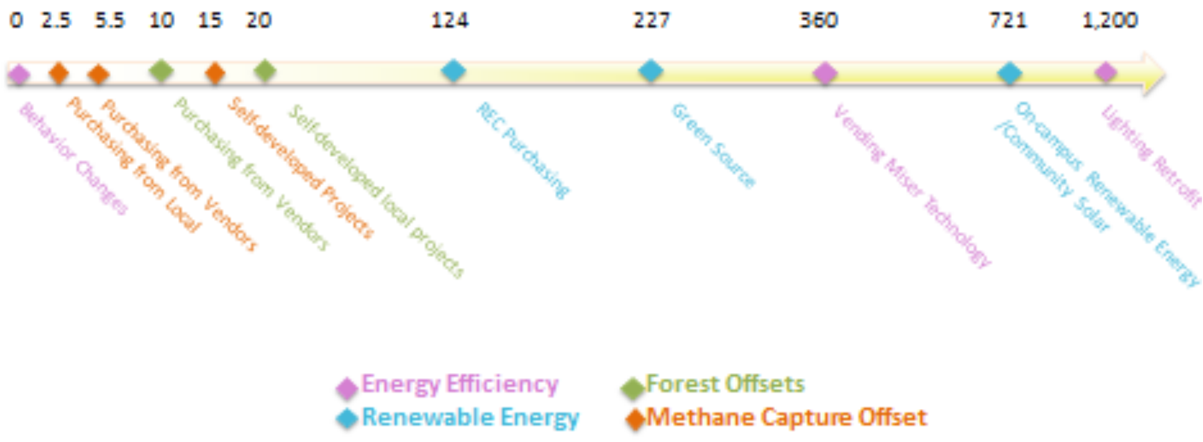
[130] Arneman D. 2009. Climate Action Plan University of North Carolina at Chapel Hill

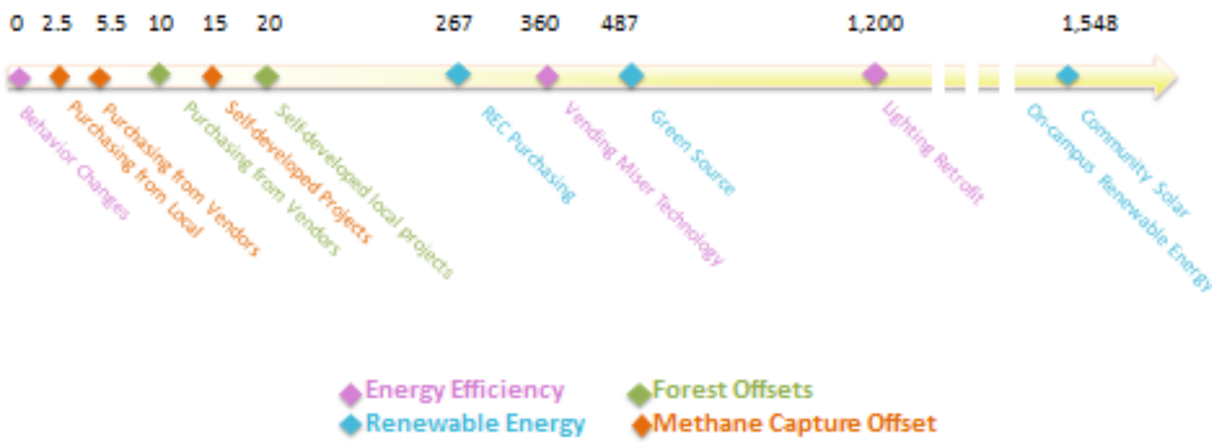
[131] Appalachian State University. 2010) Toward Climate Neutrality. http://sustain.appstate.edu/sites/sustain.appstate.edu/files/toward_climate_neut rality.pdf

Appendix F. Price lines

Price line for expected offset costs in 2040 ($/MTCO2e)



Price line for expected offset costs in 2040 ($/MTCO2e)



Appendix G. Quality of Co-Benefits

Criteria	Definition
Economic:	
Scalability	Scalability refers to whether a project can be expanded in size to generate more offsets. The best scalable projects benefit from economies of scale – as the project grows, efficiencies are gained and fewer resources are needed to produce additional offsets. The ideal scalable offset project has few, if any, barriers to expansion and is easily replicated/expanded to generate more offsets at a lower cost per offset.
Job Creation	Job creation refers to the creation of paid employment opportunities particularly for unemployed individuals. Jobs that are long-term (1+ years) are valued more highly than short-term contracts (0-12 months). The ideal offset project that meets this category creates a significant number of long-term jobs.
Environmental:	
Air Quality	Air quality refers to the health of Earth's atmosphere and the cleanliness of ground-level air. A good project would reduce the negative impacts of air pollution by decreasing the number of harmful pollutants such sulfur dioxide and particulate matter from entering the air.

Water Quality/Stormwater Quality	Water quality refers to the health of Earth's streams, rivers, lakes, and oceans. A good project would reduce the negative impacts of pollution by decreasing the number of harmful pollutants such as nitrogen and phosphorus from running off into water ways. Projects that reduce stormwater runoff should also be considered as they can lead to increases in water quality and a decrease in the amount of infrastructure needed to manage high stormwater flows.
Biodiversity	Biodiversity refers to the variety of flora and fauna within an area. A good project would maintain or lead to an increase in the variety of native flora and fauna to an area.
Land Use / Soil Quality / Erosion Control	Land use refers to the availability and quality of the land. This includes the project's effects on soil quality, erosion control, land availability, and land use. An ideal project either maintains or increases the quality of the land and the availability of the land for environmentally beneficial uses.
Location:	
Location	Location refers to the proximity of the project to Duke University. A good project is located locally, particularly within the southeastern United States, and is accessible by students, faculty, and staff for research and educational purposes.
Benefits to Duke University:	

Public Relations	The project is likely to foster good publicity for Duke University through print, social media, or televised sources.
Duke's Energy Security / Risk management	Energy security and risk management refer to diversifying the sources of energy that Duke University uses and ensuring that the sources are reliable and inexpensive.
Direct Return on Investment	Return on Investment refers to the ratio of revenues/benefits from a project to the expenses/costs from a project. The higher the return on investment the better for a project because you could be able to reinvest the revenues into scaling the project.
Partnerships	The project results in the formation of longstanding and impactful partnerships between Duke University and other institutions
Costs to Duke University:	
Cost per offset	Cost per offset refers to the number of dollars that are required to acquire one offest (1 metric ton of CO2 equivalent). The lower the cost the more offsets can be purchased.
Effort	Effort refers to the time required from DCOI Sustainability staff to research, implement, and manage a project.
Opportunity Costs - partnerships/politics	Opportunity costs refer to the alternative projects or opportunities that could be limited by adopting another project. Specifically, good projects should not have negative impacts on people politics and partnerships.

Appendix H. Scope 2 criteria[132]

All contractual instruments used in the market-based method for scope 2 accounting shall:
1. Convey the direct GHG emission rate attribute associated with the unit of electricity produced. 2. Be the only instruments that carry the GHG emission rate attribute claim associated with that quantity of electricity generation. 3. Be tracked and redeemed, retired, or canceled by or on behalf of the reporting entity. 4. Be issued and redeemed as close as possible to the period of energy consumption to which the instrument is applied. 5. Be sourced from the same market in which the reporting entity's electricity-consuming operations are located and to which the instrument is applied.
In addition, utility-specific emission factors shall:
6. Be calculated based on delivered electricity, incorporating certificates sourced and retired on behalf of its customers. Electricity from renewable facilities for which the attributes have been sold off (via contracts or certificates) shall be characterized as having the GHG attributes of the residual mix in the utility or supplier-specific emission factor.
In addition, companies purchasing electricity directly from generators or consuming on-site generation shall:
7. Ensure all contractual instruments conveying emissions claims be transferred to the reporting entity only. No other instruments that convey this claim to another end user shall be issued for the contracted electricity. The electricity from the facility shall not carry the GHG emission rate claim for use by a utility, for example, for the purpose of delivery and use claims.
Finally, to use any contractual instrument in the market-based method requires that:
8. An adjusted, residual mix characterizing the GHG intensity of unclaimed or publicly shared electricity shall be made available for consumer scope 2 calculations, or its absence shall be disclosed by the reporting entity.

[132] World Resource Institute. 2014. GHG protocol scope 2 guidance executive summary. http://ghgprotocol.org/files/ghgp/Scope2_ExecSum_Final.pdf

Appendix I. Methane capture calculation

According to the Intergovernmental Panel on Climate Change (IPCC), the Global Warming Potential (GWP) of methane in a 100-year time horizon is twenty-three, which means that methane is 23 times more potent than CO_2[133]. Based on the reaction formula:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2\,H_2O$$

The molecule mass ratio of methane and carbon dioxide is:

$$44.01\text{g mol}^{-1}/16.04\text{g mol}^{-1} = 2.74$$

Therefore, combusting 1 metric ton of methane will generate approximately 2.74 metric tons of carbon dioxide. As a result, the combustion of methane reduced the release of metric ton CO_2 equivalent by:

$$23 - 2.74 = 20.26$$

[133] Intergovernmental Panel on Climate Change. 2001. 6.12.2 Direct GWPs. http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg1/248.htm